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AMERICAN PHILOSOPHICAL SOCIETY

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VOL. XLVI JANUARY–APRIL, 1907. NO. 185.

Stated Meeting January 4, 1907.

President SMITH in the Chair.

An invitation was received from the Reale Istituto d'Incoraggiamento di Napoli inviting the Society to be represented at the celebration of the completion of the first centenary of its existence on December 31, 1906.

The Secretaries were instructed to express suitably the regret of the Society that the invitation was received too late for the Society to be represented at the celebration.

The decease was announced of Alexander J. Cassatt at Philadelphia on December 27, 1906, æt. 67.

The following papers were presented:

"The Geology of the San Francisco Peninsula," by RODERIC CRANDALL. (See page 3.)

"The Cathodic Precipitation of Carbon," by WILLIAM BLUM and EDGAR F. SMITH. (See page 59.)

The Judges of the Annual Election of Officers and Councillors held on this day between the hours of two and five in the afternoon, reported that the following named persons were elected according to the laws, regulations and ordinances of the Society to be the officers for the ensuing year:

PROC. AMER. PHIL. SOC., XLVI. 185A, PRINTED JULY 12, 1907.

President

Edgar F. Smith.

Vice-Presidents

George F. Barker, William B. Scott, Simon Newcomb.

Secretaries

I. Minis Hays, Arthur W. Goodspeed,
Edwin G. Conklin, Morris Jastrow, Jr.

Curators

Charles L. Doolittle, William P. Wilson, Albert H. Smyth.

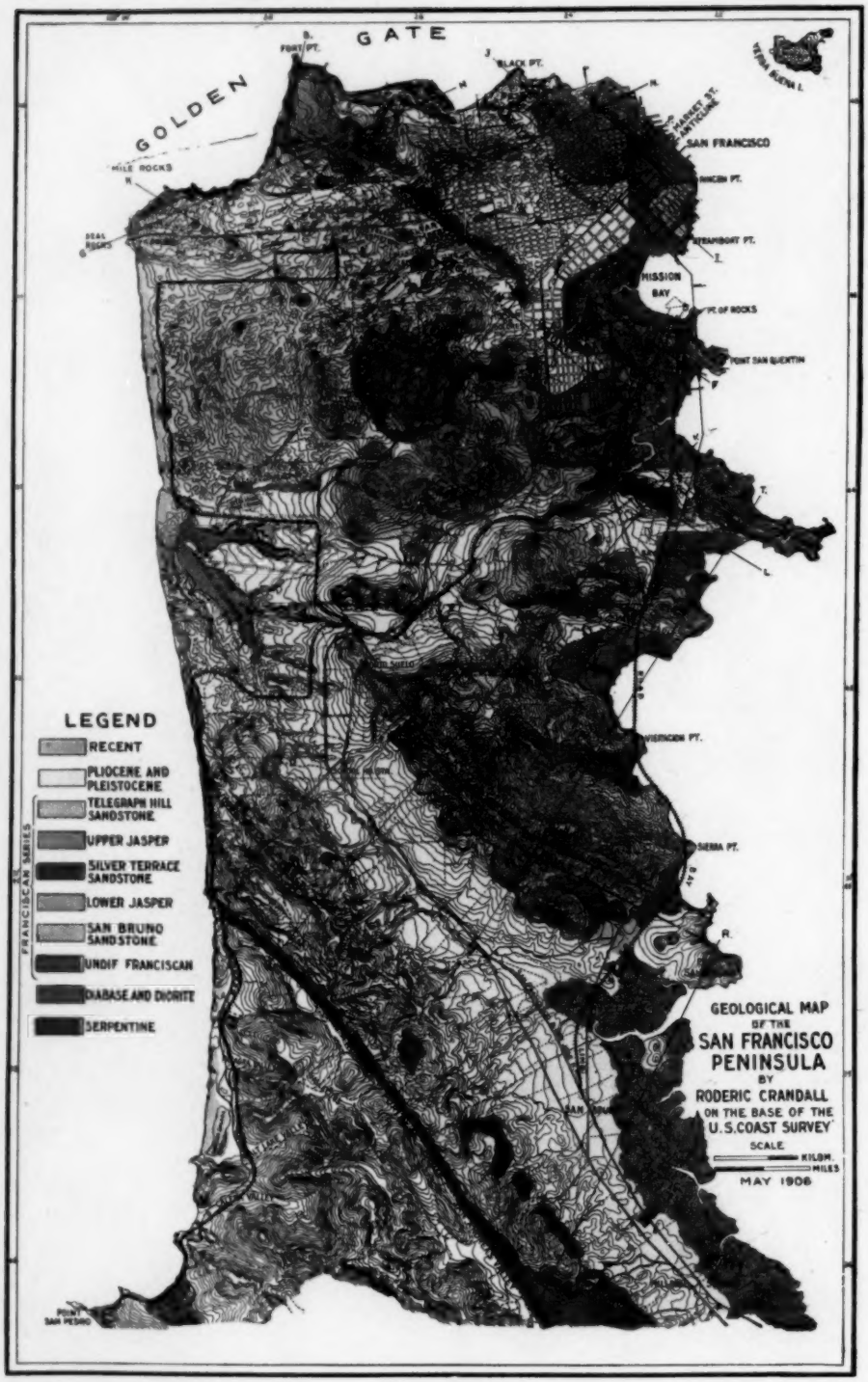
Treasurer

Henry LaBarre Jayne.

Councillors

(*To serve for three years*)

Richard Wood, Samuel G. Dixon,
J. G. Rosengarten, Henry F. Osborn.


GOLDEN GATE
FORT PT.
BLACK PT.
MARKET ST. EXTENDED
SAN FRANCISCO
MILE ROCKS
SEAL ROCKS
STEAMBOAT PT.
MISSION BAY
PT. OF ROCKS
POINT SAN QUENTIN
POINT SAN PEDRO
YERBA BUENA I.
LEGEND
RECENT
PLIOCENE AND PLEISTOCENE
FRANCISCAN SERIES
TELEGRAPH HILL SANDSTONE
UPPER JASPER
SILVER TERRACE SANDSTONE
LOWER JASPER
SAN BRUNO SANDSTONE
UNDIF FRANCISCAN
DIABASE AND DIORITE
SERPENTINE
GEOLOGICAL MAP OF THE SAN FRANCISCO PENINSULA
BY
RODERIC CRANDALL
ON THE BASE OF THE U.S. COAST SURVEY
SCALE
KILOM.
MILES
MAY 1906

THE GEOLOGY OF THE SAN FRANCISCO PENINSULA.[1]

(WITH A MAP.)

BY RODERIC CRANDALL.

(*Read January 4, 1907.*)

INTRODUCTION.

The main points to be covered in this paper will be stated in the beginning. These are:

1. A description of the terranes mapped with an outline of the petrography of each.

2. A description of the structure of the area with the resulting physiography.

3. A general discussion of five points of special interest: The age of the non-crystalline sedimentary rocks of the Franciscan or Golden Gate series; the origin of the Merced series; the origin of the jaspers, serpentines and metamorphic schists. In the general discussion it will be realized that this is the application of information from work done by others to local problems, in an endeaveor to throw any light possible upon some of the complex problems of the Coast Range geology.

The actual field work has been much facilitated by the good maps available. On the whole area the map of the U. S. Geological Survey has been found excellent, the topography of this map being mostly the work of the U. S. Coast and Geodetic Survey. In the city proper the map of Britton & Rey was found very good for street location. The photographs with the exception of three, two of the anticline near San Bruno point and one of the relief map of San Francisco, are the work of Mr. Robert Moran. The three excepted were taken by Mr. Berton Crandall.

[1] A thesis for the degree of A.M., presented to the Department of Geology of Stanford University, April, 1907.

II. Geological Terranes.

There are six geological terranes represented on the San Francisco peninsula.

I. The Montara granite.
II. Franciscan or Golden Gate series.
III. Merced series (Pliocene).
IV. Pleistocene and recent including the sand dunes derived from the Pleistocene.
V. Serpentines.
VI. Igneous intrusives other than peridotite.
VII. Schists.

I. The Granites.—The Montara granite does not properly belong within the area mapped, but it deserves mention in this connection because of its direct relation to the Franciscan series and the problem of the age of the latter. It belongs to the oldest rocks that appear in the Coast Ranges but is considered to be younger than the crystalline limestones and schists that occur exposed further south in these same ranges. The age of the schist and limestone is unknown and the age of the granite is likewise unknown further than that it is older than the Franciscan series, and is considered by Dr. Fairbanks to be older than the granite of the Sierras, which is intrusive in the upper Jurassic sedimentary beds.

II. The Franciscan Series.—The Franciscan series, which is the one of chief interest, rests upon the eroded surface of this granite as exposed on the northwest end of Montara Mountain near Devil's Slide. The lowest beds of the series are conglomerates containing boulders of granite that lie directly on the igneous rock. The petrographic evidence shows that the sandstone is derived mainly from the erosion of this or some similar igneous rocks, and is necessarily arkose.

The Franciscan series proper consists of five beds in the following order.

1. *Coarse Conglomerate* containing large boulders of granite.

2. *The San Pedro Shales.*—These are thinly bedded black shales having a thickness of approximately four thousand feet. This sec-

tion is exposed in the cliffs north and south of San Pedro Point for which they are named. The shale is very similar throughout, being grayish black, close grained and hard. It is in thin layers

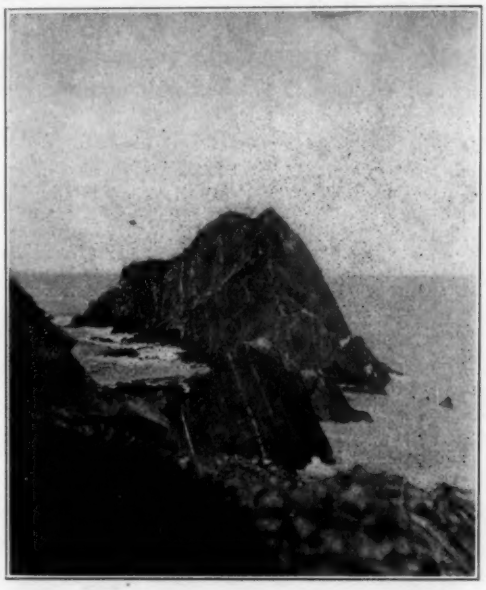


FIG. 1.

San Pedro Point, showing the beds called San Pedro shale dipping northeast.

varying in thickness from an inch to twelve or fourteen inches and occasionally interbedded with fine and coarse grained sandstones that grade into granite-bearing conglomerates which are not persistent. The beds weather into oval forms, the outer surface of a lump often being marked with ridges that define the oval forms into which the shale breaks.

3. *Limestones.*—Overlying this shale series is a limestone partially crystalline in general, and wholly so in places, but more commonly interbedded with jasper layers approximating an inch in thickness. This limestone occurs in Calera Valley where it forms several small hills, and it continues intermittently toward the southeast, the largest area being on Cahill Ridge. No work was done upon this limestone but it has been described by Professor Lawson

as showing, microscopically, the presence of many foraminifera and is called by him foraminiferal limestone.[1]

4. *San Bruno Sandstone.*—Above the limestone come the most characteristic beds of the series. These are shales, and sandstones, which occasionally have coarse conglomerates interbedded with them. With the shales are also large accumulations of pyro-clastic materials which are confined to a fairly well defined horizon just below

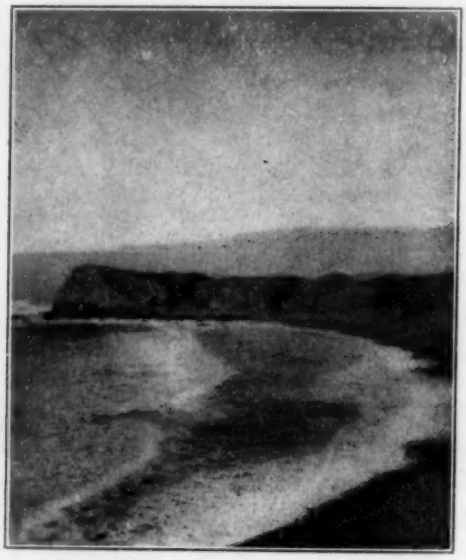


FIG. 2.

San Pedro shale beds dipping southwest; a point just north of San Pedro Point.

the jasper beds. In mapping, these volcanic tuffs have not been differentiated from the rest of the series. It is the weathering of these tuffs that gives rise to the most of the numerous and varied forms of metamorphic rocks, which, in the field, have been called greenstones.

The larger part of this horizon is made up of sandstone proper, which, when fresh, is a hard, blue gray rock, generally showing but few bedding planes, the dip being only discernible where thin beds of shale are present.

[1] 15th Ann. Rept. U. S. Geological Survey, p. 405.

This phase of the series is well exposed in the large quarries in the city of San Francisco. One just northwest of Ocean View, and another about one half mile south of Ocean View show especially good sections. The black shales that occur in this sandstone are well exposed in the cuts made at Visitation Point and north of there, along the line of the new bay shore road of the Southern Pacific railway.

The top of this sandstone series is a few hundred feet of sandstone that is very generally characteristic wherever found. The noticeable thing is the form in which it weathers, a soft light yellowish gray rock with pink spots throughout it. The persistence of this character of the rock has been noted at the several places where it is exposed, even when the exposures are some distance apart. It is best shown about half a mile east of the Cliff House, but specimens from the southwest side of the San Bruno mountains, and Sawyer's Ridge near San Francisco, and from Alum Rock canyon and San Felipe Valley, in the Mount Hamilton region, are macroscopically identical. It is to be noted here that in all four of these places the horizon is the same, that is directly under the lowest bed of the red jasper.

5. *Jaspers.*—The next group of beds in the Franciscan series is the jasper. This consists of three beds, which in this area, have been mapped separately. At the bottom of the group is the lowest jasper. This is a bed approximating five hundred feet in thickness. Lying upon this are sandstones, shales, tuffs, and lignites with an approximate thickness of four hundred feet. Over this is the upper bed of jasper which is at least a thousand feet in thickness.

These jaspers are thinly bedded flinty layers, varying from a fraction of an inch to an inch in thickness, and very persistent in character. They are dull reddish, stained with iron oxide, but varying in places to green, white and other colors more locally. In places the jaspers are traversed by white veins of quartz or calcite.

6. *Telegraph Hill Sandstone.*—The top of the Franciscan series, as exposed at San Francisco, consists of eight hundred or a thousand feet of sandstones and shales that is very similar to that underlying the jaspers. This sandstone is particularly well exposed in Telegraph Hill where it is quarried extensively. The shales of this

series are also exposed here but are best shown where Second street has been cut through Rincon Hill, from Mission street eastward. In this part of the series the volcanic tuffs are also to be seen but only in small exposures.

So far as is known the Franciscan series is a unit, and though the complete section cannot be crossed continuously, owing to structural features, outside of the unconformity between the two jasper

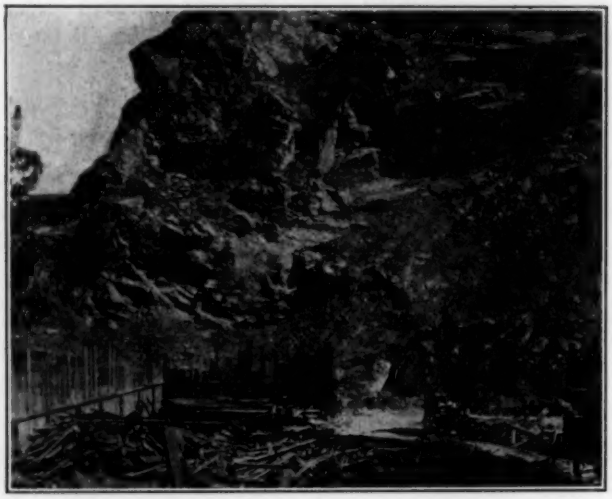


FIG. 3.

Jointing planes in massive sandstone exposed in a quarry on the northeast side of Telegraph Hill.

beds, which is regarded as local, the series is here geologically a continuous one.

The Franciscan series as a whole is much fractured, folded and metamorphosed, even more so in other regions than on the San Francisco peninsula. This deformation seems to have been general and the unaffected regions are smaller and more local than the affected ones.

The effects of this deformation are shown in the present state of the beds. The peculiar shapes into which the San Pedro shales break are due to the movements to which they have been subjected. The most noticeable effect in the sandstones is the many joint planes

which in an open quarry obscure the original bedding planes. Professor Lawson has attributed these joints to weathering but their occurrence in fresh rock after the same fashion leads to the belief that they are of dynamic origin, though they are much more evident in the wethered beds. In the open quarries, planes along which

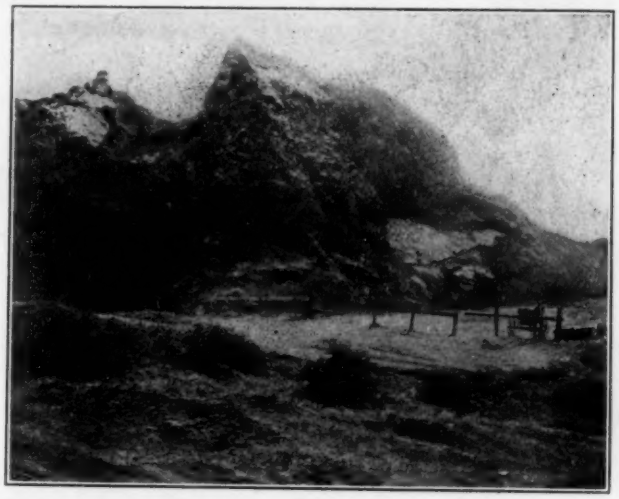


FIG. 4.

Slickensided faces in jasper, shown at a quarry on Lobos Avenue near the ocean.

slipping has occurred and small faults from a few feet to a hundred feet, may be observed crossing each other at varied angles and in many directions. In the small faults the sandstone may be seen altered to a thickness from three to ten inches on either side of the fault plane. Secondary silicification is widespread in these sandstones, giving rise to barren quartz veins in places, some of which were the cause of the gold mining excitement on San Bruno mountain some years ago.

The tuffs also show marked effects of regional disturbances, resulting in the formation of dark green, hard, compact rocks, which were termed greenstones in the field until their true character was ascertained. Examples of this rock may be seen in the small islands along the cliffs of the Golden Gate, at Silver Terrace hill and at Mussel Rock.

The jaspers more than any other rocks, show the result of crushing in the contortions and wrinklings of their layers. They seem to be beds of great elasticity, that bend and twist without breaking.

FIG. 5.

Local folding and faulting of jaspers at Stow Lake, Golden Gate Park.

In nearly every place where they are exposed they show either parallel successions of close folds, or wavy structure, which is particularly well emphasized by their thin bedding.

PETROGRAPHY OF THE FRANCISCAN ROCKS.

Sandstones.—The sandstone, in the hand specimen, when fresh, is a bluish gray rock; when weathered it is a dull yellowish brown. In the field this sandstone is characterized by two of its constituents, the small flakes of shale and the presence in certain localities of considerable amounts of brown mica. Slides of this rock from various places are very similar except for the presence of mica, and in nearly all cases show that it is sandstone derived almost entirely from the weathering of an igneous rock—in other words it is an arkose.

The grains are small and angular rather than rounded, set widely

apart in a large amount of cementing material. This cementing material seems partly silicious and partly ferruginous but at times it is calcareous. Most of the grains appear to be quartz, but when optical figures were attempted, on various sections, biaxial figures were obtained showing a portion of them to be feldspars instead of quartz. Plagioclase is present in all the slides and is noticeable by its twinning. In one slide a large angular rock fragment was observed which was composed of quartz and plagioclase. The extinction angle of this plagioclase gave about 18°, placing the feldspars with the acid labradorites or near the oligoclase. Dr. Becker in his monograph on the coast quicksilver deposits, remarks on the uniformity of this arkose throughout the state. He says the typical feldspar is oligoclase with occasionally a more basic one, quartz and orthoclase being in about equal amounts.

One point of interest in connection with this sandstone is the presence of feldspars. As the experiments of M. Daubrée show that pulverized feldspars change to kaolin very rapidly in the water, the conclusion is that these rocks are shallow water deposits.

The presence of the orthoclase and oligoclase with quartz, in the slides, taken with field relations between this sandstone and the Montara granite leads to the conclusion that this granite may be part of this land mass, though it is not necessarily true that this sandstone is all formed from the Montara granite, but from a granite that possibly underlies the whole Coast Range and of which this is a part.

Small fragments of brown mica are often present, and little, long flakes of black shale that appear blue black in ordinary light, but which are not affected by polarized light.

Quartz appears throughout the rock in small veins, traversing it in all directions. These veins are newer than the mass of the rock, but they were formed before the dynamic movements took place, for they give the same wavy and banded extinction that all the quartzes and feldspars do in the main rock mass. The secondary quartz shows fine aggregate texture with each little crystal of the aggregate having its own position of extinction. Secondary quartz of this nature is seen in nearly all of the rocks of the Franciscan series.

Calcite, another secondary mineral, is present and is later than

the quartz, cutting through the rock regardless of previous fractures. The extinction of the calcite is not wavy, due to the fact that it is later than the period of movement.

Slides were made of sandstone from the specimens taken from within four inches of the contact of the serpentine and sandstone at the Presidio and the Potrero. No metamorphism was observed, except for a slight difference in the cementing material, showing that no contact metamorphism has taken place here, even at so short a distance from the serpentine. A slide made from sandstone taken from the face of a small slip zone in one of the open quarries, shows the results of movement in this rock. The cementing material had been changed to a fibrous green mass that was not affected by polarized light. The quartz was all recrystallized into the fine aggregate texture mentioned before, but in some cases the original form or outline of the sand grains could still be seen.

This is interesting to show the amount of metamorphism produced by the intrusion of a large mass of periodotite, and by movement resulting in a small fault.

Tuffs.—The much weathered tuffs appear as dark green or much iron stained crumbly beds, and are well characterized by their popular name of "rotten rock." They are much broken up beds that can easily be dug into with a hammer, and possess no visible bedding planes unless associated with sandstone or shale. This is the form of the rock under ordinary weathering but when metamorphosing agencies have acted upon it, it becomes a hard green rock, with much quartz and has the appearance of a metamorphosed jasper.

Slides were made from this tuff from Baker's beach, Point Lobos beach, Silver Terrace hills, Potrero and several other localities, the best specimens being obtained from Silver Terrace.

At the last named place the tufaceous nature of the rock can be plainly seen in the weathered specimens. In a quarry near Silver avenue and First street the relation of the fresh to the weathered rock is seen. Here there appears to be a dike of green rock intruded into the tuff, but a microscopic examination shows the apparent green dike and the brown tuff to be the same. In a street cut on Railroad avenue near Nineteenth avenue the cause of the meta-

morphism of the tuff is plainly seen in the presence of a dike of diabase which appears to have a width of at least one hundred feet. Further south on Railroad avenue the presence of much broken and contorted jaspers determine the proper horizon of the tuffs.

The specimens for this work were taken from the new Southern Pacific railway tunnel through the hill on Railroad avenue.

In a slide the main part of the rock is a dark green mass that does not react to either ordinary or polarized light. Tests with hydrochloric acid show that it is mainly amorphous silica stained with iron. Set in this groundmass are clear irregular shaped crystals some of which are quartz and some are feldspars. Plagioclases showing banded twinning and wavy extinction are present and the measurement of extinction angles, though not entirely accurate, gave about 18°. Rock fragments were seen in one slide and these were micro-perthite, intergrowth of orthoclase and albite. This with the presence of the untwinned feldspars led to the conclusion that the twinned feldspars belong to the albite group, although the extinction angle is rather high, due perhaps to inaccuracy in measuring a feldspar with wavy extinction. No large amount of ferromagnesian minerals is present, small amounts of a brown mica being the only ones observed.

The quartz of each grain present has been recrystallized into minute aggregate texture, the average size of the new grains being about .02 mm. in diameter. Small patches of the same dark blue shale are present that were noted in the sandstone, as are also secondary quartz and calcite veins.

This tuff that has just been described is from the Silver Terrace hills; those from Baker's beach region show the presence of two other minerals, chlorite or a chlorite-like mineral and irregular masses of pyrite.

The chlorite is present in long fibrous seams and irregular patches. It is strongly pleochroic from dark green to yellowish green. In one slide this mineral appears along a seam in the rock in the form of fibrous spherulites ranged on both sides of the seam, and growing toward the center. Under cross nicols it shows anomalous colors, Berlin blue, yellow and brown, with a wavy extinction that is approximately parallel.

According to Rosenbusch, chlorites are common minerals as secondary products in altered tuffs, being derived from the aluminous members of the biotite and phlogophite micas, pyroxenes and amphiboles. Just what minerals the chlorite in these tuffs was developed from is indeterminable from any slides made, but it represents the presence of some of the ferro-magnesian minerals previous to metamorphism.

The presence of albite, microperthite, orthoclase and quartz places the tuff with the acid group, but not definitely.

This tuff shows three periods of metamorphism: first, the formation of pyrite and chlorite; second, the introduction of the secondary quartz veins, which show recrystallization and wavy extinction, and which have cut through the chlorite; third, the introduction of veins of calcite that do not show wavy extinction and which are later than the quartz.

Jaspers.—The hand specimens of the jasper need little description as they are already well known. Very little petrographic work was done upon them but a resumé is here given of the results of the examination made by Dr. Hinde.[1]

Sections were made from the chert from Angel Island and from the Buri-Buri ridge, San Mateo county. The radiolaria appear as rounded outlines, with diameters of .055 mm. to .3 mm., set in a matrix of silica. The structure is not retained, the walls having graded into the silica matrix. In general the silica of the cast differs from that of the main rock mass, which shows a minute aggregate form.

All the forms were poorly preserved, making the exact determination unsatisfactory, and specific correlation impossible with other known radiolaria. In general the types resemble those from the Cretaceous and Jurassic of Europe. Dr. Hinde has given a partial identification of certain species, and plates illustrating these accompany his paper.[2]

III. Merced Series (Pliocene).—The Merced series is well exposed along Seven Mile beach, presenting a measured section

[1] The Radiolarian Chert of Angel Island, Bulletin Department Geology, University of California, I, No. 7, p. 235.

[2] *Loc. cit.*, p. 240.

over a mile in thickness. The beds are only partially consolidated except locally. The series consist mostly of sands and clays bedded from a few feet to over a hundred feet in thickness. Certain thin conglomerate layers are much harder and more resistant than others; these consist of jasper pebbles and broken shells. This hard conglomerate is well exposed at Mussel Rock and along the ridge southeast of there, lying along and near the Franciscan rocks. There are dark or almost black clay beds in the series and these are the ones that are most fossiliferous. As the upper part of the section is approached the beds are softer and more sandy. There are a few small layers of lignitic material and in the cliffs just south of the Life Saving Station there is a layer of white volcanic ash. Along the cliff this layer of ash has a fairly constant thickness of ten or twelve inches.

Dr. Ashley has described these beds more thoroughly and has given their identification in his paper.[1]

IV. Post-Pliocene.—Above the Merced series lies the Pleisto-

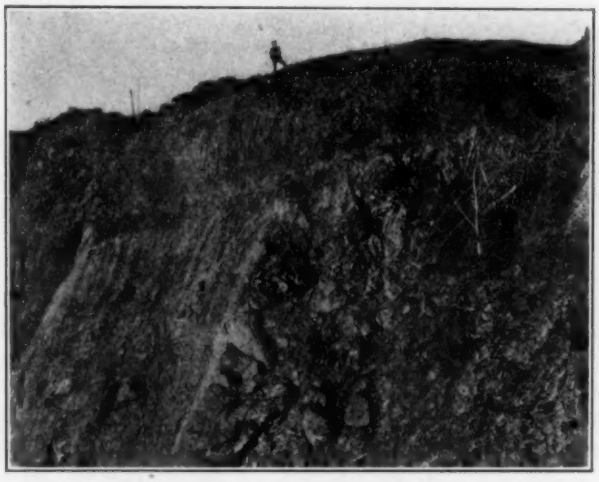


Fig. 6.

Pleistocene and recent deposits overlying the serpentine of the Presidio sill.

[1] Neocene Stratigraphy of the Santa Cruz Mountains, Proc. Cal. Acad. Sci., Series 2, V, 312.

cene, consisting of a thickness of perhaps one hundred feet of partly consolidated clay. Dr. Ashley mentions a thickness of two hundred feet south of Mussel Rock. In the area mapped the thickness of the Post-Pliocene beds was difficult to determine but is probably not over one hundred feet.

The question of the conformity or unconformity of the Pliocene and Pleistocene is one that is yet to be decided and is not evident in this area. No paleontologic work was attempted upon these beds.

V. SERPENTINES.—In the city the serpentines form a prominent terrane; the best exposures for study are in the large hills at the Potrero. The serpentine is found in several places, and is always

FIG. 7.

A conglomeratic effect in serpentine as exposed in a quarry on Potrero Ave., near the railroad.

characterized by the blue green appearance, and by a lack of soil and vegetation over the surface. In the quarries of the Potrero the original peridotite rock may be seen. This appears as large black boulders in the serpentine, giving the appearance of a coarse conglomerate. Each of these boulders is separate from the others and coated with from one to many inches of slickensided serpentine. This shows the breaking up of the peridotite mass and the large

amount of movement that has taken place, due to the increase in volume in the formation of serpentine.[1]

The peridotite is the fresh facies of the serpentine, and has been shown petrographically to be the rock from which the serpentine proper is derived. The other or slickensided facies of serpentine is the one with which nearly everyone is familiar. It is blue to green in the hand specimen, soft and smooth to the touch. It flakes roughly, giving always new slickensided faces showing that there have been movements in every little particle of the rock. There are occasionally varying streaks of a hard brown rock that seems different from the main mass but which petrographically is just the same.

Associated with these serpentines are small veins of magnesite, some of it of the fibrous variety, and some hard and compact. Another rock that is found with the serpentines has been termed "silicious carbonate sinter" by Professor Lawson.

This material is a weathered product of the serpentines. It is a hard, light-colored rock showing lines of silicification throughout. It is believed to have been produced by a leaching of the magnesium, in the form of a carbonate, from the serpentine, with a simultaneous redeposition of the silica present as amorphous silica, and more or less stained with the iron from the original rock.[2] The magnesium leached out probably goes toward the formation of the magnesite veins common in the serpentine. Rock sections show but little except the lines of silicification, as the amorphous silica does not react in the ordinary or polarized light.

Petrography of the Serpentines.

The petrography and a few chemical analyses of the serpentines that are available are of much interest.[3] The description of two facies of the serpentine will be given, the massive facies and the slickensided facies.

[1] G. P. Merrill gives 33 per cent. as the increase of volume due to formation of serpentine by the hydration of olivine.

[2] Knopf, A., An Alteration of Coast Range Serpentine, Bulletin Department Geology University California, IV, No. 18, p. 425.

[3] Dr. Palache has described the serpentines in his paper on the lhezolite serpentines of the Potrero. Bulletin Department of Geology University California, I, No. 5, p. 235.

Massive Facies.—Fresh specimens of the massive facies were taken from the Potrero and the Presidio.

From the Potrero no sections were obtained in which serpentine was not present. Other constituents or original minerals present in the peridotite are as follows: orthorhombic pyroxene enstatite, monoclinic pyroxene diallage, olivine, magnetite, and chromite. These constituents give the serpentine the name of lhezolite, the original rock being a peridotite.

The largest constituent of this rock appears to be the pyroxene diallage. The crystals show no definite form but are in long irregular shapes, possessing marked cleavage in the long direction. Basal sections occasionally show the parting characteristic of diallage. The relief is medium and the crystals are colorless in ordinary light. Under cross nicols the colors are high, most commonly upper first and second order. The extinction angle varies with the different sections from 18° up, the largest angle measured being 48°, the commonest about 43°.

Enstatite, the orthorhombic pyroxene, occurs in lesser quantities than the diallage and is indistinguishable from the diallage in ordinary light, the relief, color and form of the sections being similar.

Under cross nicols the colors are low, blue grey of the first order in a slide of proper thickness. Being orthorhombic the extinction is parallel and so may be distinguished from the diallage.

In one section fine multiple twinning was observed in the enstatite; the extinction was almost simultaneous for the two sets of lamellae, making it not especially noticeable. The lines of twinning made an angle of over 30° with the direction of extinction, but because of lack of similar sections the face of twinning was not determined. Rosenbusch remarks that the twinning of enstatite is not common. Both the pyroxenes showed in most of the slides with serpentine formed through them with lattice work effects.

Olivine is present only in small irregular grains wholly surrounded by serpentine due to its having weathered faster than the pyroxenes.

In ordinary light it is clear and colorless and is distinguished from the pyroxenes by its higher relief and lack of cleavage. In

polarized light its colors are high, being upper second in general. Groups of these olivine grains situated together would often extinguish simultaneously, showing that the original crystals of this mineral were quite large.

Magnetite in black patches and chromite in brownish black masses were present, scattered through the serpentine and as inclusions in the diallage.

The pyroxenes showed marked wavy extinction, due to the amount of pressure and movement to which they have been subjected.

The serpentine appears yellowish and greenish in ordinary light and surrounds the grains of olivine and in lattice work forms through the pyroxenes. It seems stained with iron to a considerable extent. In polarized light it is blue grey with a felted appearance and compensatory extinction.

Slickensided Facies.—The slickensided facies is similar to this except that none of the original minerals remain, the serpentine derived from the pyroxenes being the same as that derived from the olivine.

ANALYSES OF SERPENTINE.

Locality.	Presidio.	Angel Island.	Mt. Diablo.
SiO_2	39.60	42.06	36.57
Cr_2O_3	.20		.33
Al_2O_3	1.94	2.72	.95
Fe_2O_3			7.29
FeO	8.45	2.88	.37
MnO			.10
NiO			.31
CaO			.14
MgO	36.90	39.53	40.27
K_2O			trace
NaO			.31
H_2O above 100°	12.91	12.04	12.43
	100.00	99.23	99.07
Analyst.	Dr. Easter.	F. L. Ransome.	Dr. Melville.

The fresh facies of the peridotite from the serpentine mass of the Presidio gave sections that showed the presence of no serpentine at all. There were two main minerals present with slight amounts of the same accessory minerals, as seen at the Potrero. Diallage and enstatite, the same as described from the Potrero, are present, the last named mineral in subordinate quantities. No oli-

vine was found at all, making this rock a true pyroxenite. That the main mass of the serpentine of the Presidio is not derived from a pyroxenite will be seen from the chemical analyses following.[1]

Analyses.—There is a marked similarity between the analyses of the serpentine from three distinct localities.

Turner mentions the gradation from peridotite to pyroxenite in the serpentine of Mt. Diablo. The analysis of the Presidio serpentine shows it to be an olivine bearing rock, so that the pyroxenite may be considered a local variation in the main peridotite magma.

VI. Igneous Intrusives.—The igneous intrusives cut the jaspers, sandstones and the associated serpentines of the Franciscan series. They consist of several closely related varieties.

The most important of these intrusive rocks occur in the Potrero, where they are intruded in the serpentine. Of this particular

Fig. 8.

Remnant of a diabase dike intruded into the serpentine of the Potrero sill.

intrusive there are two facies: hypersthene diabase, and hornblende diabase or epidorite. The others of these intrusives from elsewhere than the Potrero are hornblende diabase, amygdaloidal diabase and

[1] These are taken from a paper of H. W. Turner, Journal of Geology, VI, 487.

hornblende diorite. The hand specimens are all more or less alike —hard green rock of close texture, only occasionally varying to a coarse grained rock in which the plagioclase and ferro-magnesian minerals are easily distinguishable with a hand lens. These will be described in the order given.

Petrography of the Igneous Intrusives.

Hypersthene Diabase.—The hypersthene diabase is the freshest rock of the series, and has the following constituents: hypersthene, malacolite, labradorite, hornblende, magnetite and ilmenite. The orthorhombic pyroxene, hypersthene, is present in small quantities. It is reddish, with a high relief, the pleochroism being fairly strong from red to greenish. The ray a is red and the ray c green. This occurs in large irregular prisms without any definite boundaries.

The hypersthene is characterized by parallel extinction. Around the border may be seen the growth of fibrous hornblende as in the malacolite. Some of the crystals showed a dark appearance due to the presence of small black rods of an unknown mineral. Besides the hypersthene are large irregular shaped crystals of a colorless augite, probably malacolite. In ordinary light it is clear and colorless with a medium relief. Under cross nicols the interference colors are about orange of the first order and the extinction angle is 45°. Twinning was observed.

The interesting thing in connection with the hypersthene and the malacolite is the derivation of secondary hornblende. Crystals of this colorless augite show the growth of pleochroic hornblende all about the border, noticeable in ordinary light, but in polarized light the hornblende has much higher colors. The cleavage of the hornblende is parallel to that of the augite but is more sharply marked. In a crystal with secondary hornblende of this character the extinction angle of the hornblende was 11° while that of the augite was 43°.

The hornblende is in crystals that do not show their derivation. It is in irregular allotriomorphic patches with a greater length in the direction of the cleavage. The pleochroism is from yellow to yellowish green to dark green, corresponding with the axes, c, b, a, with an absorption scheme $a > b > c$. The extinction angle, $c : c' = 17°$.

The texture is typically ophitic, the feldspars are long and lath-shaped and idiomorphic with regard to the other minerals. Twinning is common and measurements of extinction angles in sections of equal illumination gave 44°, placing them between labradorite and anorthite. The feldspar shows wavy extinction in all cases.

Ilmenite is present in black irregular patches surrounded by the derivative mineral leucoxene. The magnetite shows borders of thin red translucent hematite. These both occur as inclusions in the other minerals, feldspars and pyroxenes.

Hornblende Diabase.—The hornblende facies of the hornblende diabase does not show any hypersthene or malacolite, but only hornblende, idiomorphic feldspars and the accessory minerals magnetite and ilmenite. Since we saw in the previous description that the hornblende was derived from the hypersthene and malacolite, then in this rock we may consider all the hornblende as secondary, making the rock a true epidiorite.

At a certain outcrop on the top of the Potrero hills, just east of the end of Twenty-fourth and near Rhode Island streets, schistose structure is developed so that the hand specimen shows it quite plainly. In a section this schistosity is not quite as noticeable, but the results of pressure are evident. There is a new mineral, some blue soda-bearing amphibole, developing in long, slender, fibrous needles around the edges of the hornblende. This mineral is considered to be glaucophane, but owing to the minute size of the crystals no optical tests were attempted. In a section of hornblende that is pleochroic from yellow to green, the glaucophane is pleochroic from colorless to blue.

Intruded in the tuffs of Silver Terrace is a dike of hornblende diabase or epidiorite. The texture of this rock is ophitic and the constituent minerals are hornblende and labradorite feldspars, with the accessory minerals, ilmenite and magnetite, as described in the hornblende diabase from the Potrero. Three secondary minerals are present, quartz and intergrowth of epidote and clino-zoisite. The quartz is in fine seams with the usual aggregate texture. The epidote and clino-zoisite occur in long fibrous or columnar aggregates. In the seams the columnar texture is most common. The crystals are small and colorless but not clear and in ordinary light

the two minerals are indistinguishable. In polarized light the epidote shows grey colors of the first order but the clino-zoisite shows upper first and second order colors. These minerals are plainly secondary but whether they are derived from the alteration of plagioclase is not apparent. When these veins are cut at right angles to the columnar length of the epidote crystals, minute cross sections are seen. These aggregates are composed of such small crystals that the compensating extinction gives the whole section a grey appearance that does not change in polarized light, with a low power objective.

Amygdaloidal Diabase.—From the north side of Visitation Valley two outcrops in place give specimens that, though badly weathered, show hornblende and feldspars. One of these rocks shows the hornblende going to chlorite in most of the slides. The chlorite is green and yellow, with a similar color in polarized light. Titanite is present in this rock in rounded grains showing rough relief and irregular cleavage cracks. In polarized light the interference colors are third order and higher, with an extinction angle that is not consistent. Near the south side of the entrance to Visitation valley is an iron stained rock that looks like a weathered conglomerate in the field. Sections of this show it to be an amygdaloidal diabase. The texture is ophitic in the lath-shaped feldspars in a groundmass of allotriomorphic hornblende. A few large crystals of feldspar occur, none of which show twinning, though most of the small ones do. The extinction angles obtained were 18°, placing them near the acid end of labradorites. The hornblende has large cavities filled with calcite mainly, but chlorite and some iron mineral are present also. The chlorite is green but non-pleochroic; in polarized light it shows blue and brown. The iron mineral is a dark reddish brown with a slight metallic lustre.

Hornblende Diorite.—A specimen of rock from the southwest side of the San Bruno mountains shows hornblende and plagioclase but without ophitic texture. The hornblende and plagioclase are the same as those already described, but it contains two new secondary minerals, spinel and titanite.

Spinel is present in large quantities, in rounded irregular grains with high relief and rough surface. Being an isotropic mineral it remains dark under cross nicols.

Titanite is present and appears somewhat similar to the spinel in ordinary light except that it is very faintly pleochroic from colorless to yellowish brown. Under cross nicols it may be distinguished from the spinel by its high interference colors. In this rock much of the hornblende has altered to chlorite, the latter being present as pseudomorphs after the former. It is pleochroic from yellow to green and hardly distinguishable from the hornblende in ordinary light. Under cross nicols, the hornblende shows second order colors, while the chlorite is greenish or blue with varying extinction. This is more clearly exemplified in the rock of the north side of Visitation Valley than in this one.

VII. SCHISTS.—The schists are all of a blue amphibole (glaucophane) variety. There are various grades from a schistose sandstone to a fine glaucophane rock.

Typical of this group is a schist from one mile east of Baker beach along the Strait. It shows nothing but fibrous masses of pleochroic blue amphibole, without any other minerals. The hand specimen is soft, blue, talcose looking rock, that might easily be mistaken for serpentine, but there was no serpentine present in the slides. This rock may be an altered clay shale.

PETROGRAPHY OF THE SCHISTS.

Basic Glaucophane Schist.—From the beach along the Strait a mile east of Baker beach come two other schists, one basic the other acid. The basic schist is a very dark rock and does not show its schistose nature. The slide contained the following minerals: hornblende, glaucophane pseudomorphed after hornblende, lawsonite, pyrite, and ilmenite. The hornblende was present only in remnants, the main part of the crystals being glaucophane. The pleochroism of the hornblende was from yellowish green to dark green but much mantled by the strong blue and violet of the glaucophane.

The elongation of the glaucophane was parallel to c'. The pleochroism was from colorless to violet, to blue, with an absorption scheme $c > b > a$. The extinction of the glaucophane varied only a few degrees from parallel while that of the hornblende in the same crystal was about 13°.

Lawsonite is present in rectangular prisms with elongation paral-

lel to c'. In ordinary light it is colorless and non-pleochroic, the relief is fairly high, with a slight cleavage in the direction of elongation. In this section the colors are upper first and second order, but in basal sections the colors and relief are not so high. The lawsonite is idiomorphic with regard to the hornblende and glaucophane.

Pyrite and ilmenite occur in irregular masses as inclusions in the other minerals. Secondary quartz veins traverse the sections.

Considering the minerals now present and the texture of the rock it seems probable that it is an altered form of hornblende diabase, the glaucophane having developed from hornblende and the lawsonite having been formed by hydration of basic feldspars.

From this same locality (a mile east of Baker beach) is a light blue fissile schist that contains two minerals, a blue soda-bearing amphibole, undetermined, and minute amounts of lawsonite scattered in the interstices between the amphibole fibres.

Acid Glaucophane Schist.—The more acid schist has the following minerals: glaucophane, a groundmass that is quartz or a mixture of quartz and feldspars, large cubes of pyrite, chlorite, titanite, white mica and a mineral determined as andalusite. The glaucophane is present in large elongated crystals with indefinite end boundaries. The pleochroism is very strong, the section being cut parallel to the direction of schistosity while the blue to violet pleochroism is most common. The quartz or feldspars, without twinning, make up the large part of the rock. This is most likely all quartz, being of a fibrous nature, and the fibres are often much twisted and distorted.

The cubes of pyrite are perfect and have affected the deposition or the recrystallization of the quartz, so that the quartz has formed in fibres, so arranged that they appear attached to the pyrite cubes, with the long axes at right angles to the faces of the cubes.

Chlorite occurs in small yellowish green patches scattered irregularly throughout the quartz, showing anomalous colors under cross nicols.

The titanite is found mainly as small irregular inclusions in the glaucophane, some also being seen in the quartz.

There is some white mica with the quartz. In ordinary light

its index of refraction in one direction is nearly the same as that of quartz, but in another position of rotation it shows a slight absorption along the cleavage lines which are parallel to its length. Under cross nicols the colors are high, at least third order, and somewhat irridescent. The last named mineral andalusite, is in radial aggregates with a marked cleavage parallel to the length and slight cross cleavage. It is nearly colorless in ordinary light and with a relief higher than that of the quartz, but lower than the titanite. In polarized light its colors are low, blue grey of the first order with right angle extinction.

It is worthy of note that though this schist is quite silicious, neither garnets or lawsonite have been developed. If the rock had a soda-bearing feldspar it may be that in the formation of the secondary minerals, after the soda had been removed, the remainder of the feldspar constituents formed this aluminium silicate.

Quartz Glaucophane Schist.—The other schist to be described is a quartzose glaucophane schist from about one mile northeast of Lake Merced. There are three minerals present: quartz, glaucophane, and white mica. The rock shows its nature in the hand specimen, appearing as a hard blue quartzite with a suggestion of schistosity.

The main mass of the rock is recrystallized cloudy quartz with fine aggregate texture.

Fine needles of blue glaucophane appear developed with their long axes parallel to the direction of schistosity. The length of these needles is considerable in proportion to their width. Measurements gave a maximum length observed as .18 mm. with an average of .10 mm. The average thickness was about .01 mm. with a maximum of about .05 mm. This shows that these needles are mostly thinner than ordinary rock section, so that pleochroism and interference colors were, for the most part, much obscured. The pleochroism of this glaucophane was from colorless to violet to blue with an absorption scheme of $c > b > a$. The extinction angle $c : c'$ is quite small, a maximum of 8° being observed. Ilmenite and pyrite are present in very minute cubes. The cloudy appearance of the quartz may be caused by the dissemination of these fine particles of iron throughout.

White mica is present, intergrown with the quartz, and is noticeable by the marked difference of relief in one position of rotation. In polarized light the colors are third order or higher.

Small veins of secondary quartz appear in the section. These show the same aggregate texture and wavy extinction as the other quartz, but may be distinguished in ordinary light by their clear and colorless appearance, as contrasted with the clouded appearance of the quartz of the rock proper. Without exception the size of the individuals of the aggregates is much larger than those of the other quartz. The average size of the grains of quartz in the main rock mass was about .02 mm. in diameter.

Further careful search may reveal schists not mapped, but such areas would not affect the structure of the region as worked out. The relations of the schists and other rocks will be considered further on in the paper.

III. Areal Distribution.

In the areal distribution the geologic order of terranes followed in the descriptive text is not adhered to. The distribution is best

Fig. 9.

Recent sand dunes near Golden Gate Park. These are derived from the Pliocene and Pleistocene deposits.

shown upon a map, and for this purpose a colored map, with necessary legend, is appended.

Merced Series.—The series that deserves first mention here is the Pliocene, Pleistocene and the derivative sand dunes. These cover the largest part of the area mapped, and because of the widespread distribution of the æolian sand, give the area the appearance of hills almost buried by sand.

The Merced series proper is confined to the long low valley lying between the Buri-Buri ridge and San Bruno mountains. The series lies upon the old Franciscan rocks near Mussel Rock and from there rises to the top of Buri-Buri ridge, follows southeast along the trend of the ridge to about two miles northwest of Millbrae, where it drops into the low hills and appears on the low lying hill to about two or three miles southeast of Millbrae. The complete southeast extent of this series is not shown on the map. Below Millbrae the streams have cut through this series exposing the underlying rocks showing that it appears only as a thin edge and that it is probably chiefly wind-blown material.

A point of interest in this connection is the exposure of the Franciscan rocks on the fronts of the steep hills west of Millbrae and of Baden. In the stream bottoms that run between these hills and in the circular-shaped basin behind them the Merced beds are in place.

Going northward along seven mile beach nearly the entire thickness of the series is exposed tilted toward the northeast. Just south of the Life Saving Station the beds disappear under the Pleistocene formation. The northeast line of the contact with Lake Merced to South San Francisco is not exposed, the rest of the eastern contact from South San Francisco to south of Millbrae, is determined by the marsh line. The obscuring of this contact along San Bruno mountains is caused by the Pleistocene materials which have been blown up against San Bruno mountains about to the five hundred foot contour in places. North of San Bruno mountains these sands cover most of the city proper, obscuring the underlying geologic structure in many places. This formation merges into the recent deposits along the flats.

San Bruno Sandstone.—The formation of next importance in

distribution is the lowest sandstones and shale beds of the Franciscan series which is represented in San Bruno mountains and which for purposes of differentiation in this paper is called the San Bruno sandstone. It is not definitely known what place this sandstone has in the Franciscan series as compared with the sandstones and shales exposed at San Pedro Point, but it appears as if the lowest part of the mountains exposed at Sierra Point was the equivalent of the middle or upper section at San Pedro.

This sandstone and shale form San Bruno mountains and the parallel ridge northeast of Guadalupe Valley; the hills known as Columbia Heights; University Mound in the southwestern part; and the southwestern part of San Miguel Hills, partly covered by the sands and disappearing under the lower jaspers. This sandstone appears in only one place north of the exposures mentioned, and that is at the Cliff House and around Point Lobos to within about a mile of Lobos Creek.

Jaspers.—The formation that overlies the San Bruno sandstone is the lowest jasper bed. This bed of jasper lies directly upon the San Bruno sandstone along the cliffs north of Golden Gate Cemetery. It disappears under the æolian sands and is exposed in only one or

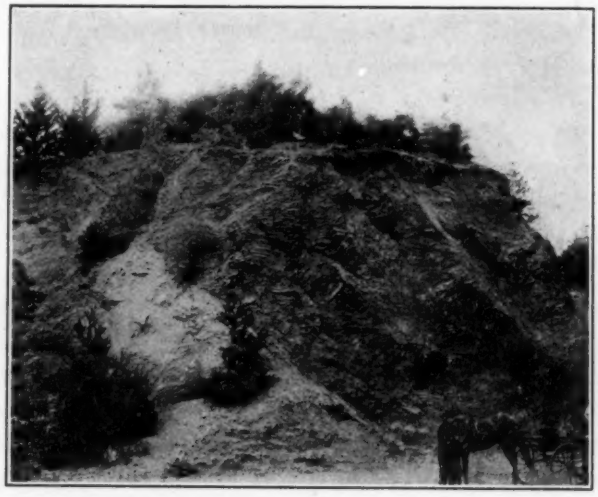


FIG. 10.

Local folding in jasper exposed in a quarry at Golden Gate Park.

two quarries near Point Lobos avenue until Golden Gate Park is reached where it is seen in Strawberry Hill, and one of the smaller hills there that has a wooden cross erected upon it. This jasper forms the crest of the ridge of hills in Sunset district, being exposed only from M to S streets. Continuing, this formation makes up the portion of the San Miguel Hills known as Sunnyside Addition, and extends around the east and north side of those hills almost to Valencia street. On the east side of the railroad tracks it appears in the southwestern part of Holly Park and in irregular areas on the northeastern side of University Mound. On the hills just north of Visitation Valley and west of Railroad avenue the entire thickness of the bed is seen. Two small hills of this jasper occur, one on either side of the entrance to Visitation Valley. Their relations are explained in the discussion of the structure.

Silver Terrace Sandstone.—Lying between the lower and the upper jasper bed is the Silver Terrace sandstone which consists of a bed of sandstone and some tuffs which, together, have a thickness of about five hundred feet. The tracing of the Silver Terrace sandstone and the associated tuff is much more difficult than tracing the jaspers. The full thickness is exposed dipping into the northeast from a point about a half mile east of Lobos Creek to a point about a half mile northeast of Lobos Creek where the upper jasper is exposed in a quarry on the Presido. It is present as an erosion remnant in Golden Gate Cemetery, but does not appear between that place and Blue Mountain. It can be traced around the west and southwest sides of Blue Mountain and Twin Peaks, and it crosses a gap between the latter place and Sunnyside Addition, and continues around the eastern side of Twin Peaks to Buena Vista Park. Erosion remnants cap the hills southeast of Buena Vista Park, Castro street hill and Dolores street hill. In the eastern part of the city it passes through the gap between Bernal Heights and Holly Park and forms the Silver Terrace hills. The sandstone forms a floor upon which rest the Hunter's Point serpentines and the two small hills southwest of Hunter's Point. On top of the serpentine forming Hunter's Point hills, is a small area of conglomerate belonging with this sandstone.

Upper and Lower Jasper Bed.—The Silver Terrace sandstone

is overlain in some places by the upper jasper bed, notably at Blue Mountain, Twin Peaks, and at Bernal Heights. It occurs in several places at the Presidio quarry, near Masonic Cemetery, on the extreme end of Hunter's Point.

Telegraph Hill Sandstone.—A sandstone called Telegraph Hill sandstone composes all the hills in the business portion of the city, Russian Hill, Telegraph Hill, Rincon Hill, Lone Mountain, Lafayette Hill, and is exposed beneath the serpentine at the Presidio, and both under and over the serpentine at the Potrero. It does not appear on top of the jasper anywhere in the city except at the Potrero, and nowhere else is its relations to the Franciscan series shown. Elsewhere in California, so far as the writer's observations go, the Cretaceous overlies the jaspers, but there have been no fossils found here to show that this Telegraph Hill sandstone belongs to the Cretaceous, and as it resembles the San Bruno sandstone petrographically and macroscopically, it is regarded as a sandstone belonging to the Franciscan series and overlying the jaspers.

Serpentines.—Across the city in a northwest-southeast direction from the Presidio to the Potrero and Hunter's Point is a line of irregular areas of serpentine. This line of serpentine is geologically continuous, though it does not appear so on account of the intervening sandstones and æolian sands.[1] The proof of this continuity rests upon the field evidence and the petrographic similarity of the serpentine. That from the Potrero was found to be a lhezolite serpentine, while that from the Presidio was found to be a pyroxenite, but, as remarked in the previous discussion of the rocks, the chemical analysis shows that olivine must be present. The Presidio rock must also be a lhezolite serpentine as is that from the Potrero. Chemical analysis would prove this point beyond a doubt. There are a few small areas of serpentine in other places, namely, in the hills at South San Francisco, Buena Vista Park, Castro street hill, Islais Creek near Holly Park, University Mound, and at several other localities.

Igneous Dikes.—The igneous dikes are present as intrusions in the serpentines of the Potrero and Hunter's Point, in the Silver Ter-

[1] Lawson, A. C., Geology of the San Francisco Peninsula. 15th Ann. Rept. U. S. Geological Survey, p. 445.

race sandstones and tuffs, and in the San Bruno sandstone in a number of places. These dikes are on the north side of Visitation Valley, near Railroad avenue, and near the entrance to the valley, and also on the southwestern slope of San Bruno Mountain, and in the little hills in the marsh, one and one half miles south of South San Francisco.

Schists.—The schists of San Francisco come mainly from one area along Golden Gate Strait between Point Lobos and Lobos Creek. The quartzose glaucophane schist described comes from the San Miguel hills about one mile north of Ingleside Race Track. The biotite schist is from just north of the entrance to Visitation Valley.

IV. Structure.

Main Faults.—The structure of San Francisco peninsula is complex but controlled in general by three main faults. The type of structure is the same as that which characterizes other parts of the Coast Ranges. These are dominant fault lines, with a general northwest and southeast trend. Parallel to these faults are the major lines of folding and minor lines of faulting. Making almost a right angle with these lines are the minor lines of folding.

Lone Mountain Fault.—Lone Mountain fault is the first of the three main faults which control the geology and topography of the San Francisco peninsula to be considered, as it crosses the city from the Presidio to Hunter's Point in a straight line. This fault may be seen only in the cliff near the Presidio. The line can be traced across the city only by the topography and by the areal distribution of the rocks. It is this line which determines the northern limits of the jaspers (excepting that at the Potrero), and the southern limit of the Telegraph Hill sandstone. As the jasper does not appear again north of this line, it is believed that the downthrow of this fault is on the northeast. This is also substantiated by the presence of a very closely compressed syncline, with its axes parallel to the fault and apparently developed by the slipping of the fault block. The throw of this fault is not known, but it is judged to be between 800 and 1,000 feet.

San Bruno Fault.—The second fault is the San Bruno fault. This is clearly a thrust fault with the upthrow of perhaps 1,500 feet

on the northeast side. It is not quite straight but enters the area on the west between the Ocean House and the Life Saving Station, follows a southeast course swinging slightly toward the north as it

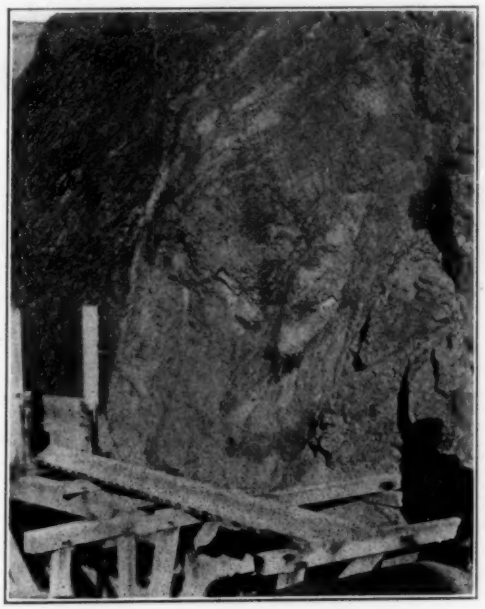


FIG. 11.

Jasper remnant resting against sandstone at the point where the Lone Mountain fault cuts the cliffs near the Presidio.

reaches the bay one half mile north of San Bruno Point. The crescent shape of the San Bruno hills is apparently directly related to the form of this San Bruno fault line.

In connection with the upthrust of the San Bruno block, an anticline has been produced parallel to the axis of the fault. At the point where the railroad turns directly west, leaving the city near Ocean View, a topographic saddle has been formed by the breaking down of this anticline. In places this San Bruno fault distinctly affects the topography: a line of low hills along the southwest side of the ridge have jasper remnants exposed on their summits, showing that they are geologically above the top of the San Bruno mountain. The anticline developed by this fault may be seen quite

plainly in two places, near Ocean View and on the bay shore north of San Bruno Point.

San Andreas-Portola Fault.—The most important fault line on the San Francisco Peninsula is the San Andreas Portola fault. It is plainly discernible in the bluffs at Mussel Rock, and from there it runs toward the southeast through San Andreas and Crystal Springs Lakes. This same fault continues to the southeast through the Santa Cruz quadrangle, where it is known as the Portola fault. This is one of the main lines of weakness in the Santa Cruz mountains, and it has been the line of movement at various times. There have been at least two important movements along this fault line,

FIG. 12.

A partial view of the anticline at San Bruno Point showing the sandstone and shale beds dipping northeast.

for the Franciscan sandstone lying northeast of the line is geologically higher than that on its southwest side. Since the movement that caused this dislocation of the Franciscan rocks there was another movement after the deposition of the Merced series which resulted in the tipping of the Merced beds toward the northeast. The steepness of the dip of these rocks increases from Lake Merced southward to Mussel Rock. This second movement brought the Franciscan beds on the northeast side into a position but slightly

lower than their original one, and there has been an apparent development of a minor syncline on the south side of San Andreas Lake parallel to the fault line in places, while the Franciscan beds on the north side of the lake dip sharply to the southwest. The total throw of this fault is indicated by the amount that Franciscan beds on the northeast side of the fault are lower than those of the same horizon on the southwest side, and that is about 500 feet.

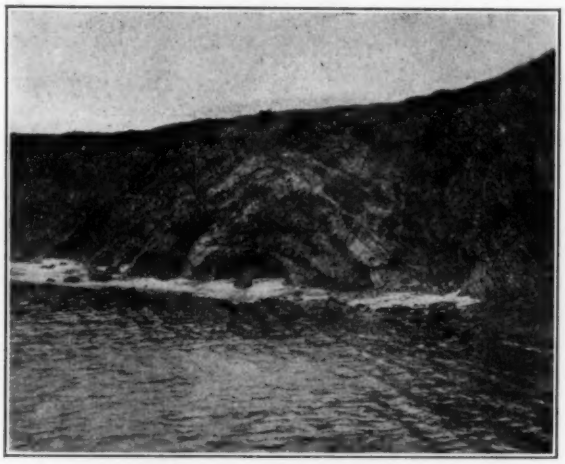


FIG. 13.

The San Bruno anticline exposed in the cliffs one mile north of Point San Bruno.

This displacement has been spoken of here as a single movement, but it must be taken as the algebraic sum of all the movements up to the present time rather than as a single movement. That the upthrow of this fault is on the northeast side is confirmed by the evidence in the Santa Cruz quadrangle where the Franciscan beds in Black Mountain are higher than the Miocene beds southwest of the fault.

Minor Faults.—Of the minor faults there are only two worthy of consideration; these are the Visitation Valley and the Wood's Gulch faults.

Visitation Valley Fault.—There are likewise two minor faults parallel to these main fault lines and possibly a third one. The

first of these has resulted in the letting down of the sandstones on the southwest side of the hills known as University Mound, and the formation of Visitation Valley. At the entrance of the valley are two little jasper remnants that have been faulted down. The line of faulting is approximately parallel to Visitation avenue, passing between the two ridges of jasper in the northeastern end of the valley.

Guadalupe Valley is parallel to this line but since it is entirely in San Bruno sandstone it is not certain whether or not its structure is the same as that of Visitation Valley. The dips of the beds on the northeast side of the San Bruno mountains are very much steeper than those on the southwest side of the ridge. This leads to the belief that the Guadalupe is a fault valley, though definite proof has not been found.

Wood Gulch Fault.—In the Merced series about one mile north of Mussel Rock there is another minor fault having a downthrow of some eight hundred feet on the southwest side. There are other small faults in the Merced beds with displacements of twenty-five feet and more, but none of them are important.

The deformation of the Merced beds shows that the San Andreas faults are of post-Pliocene age but the age of the faults across the city of San Francisco from the Presidio to the Portrero (Lone Mt. fault) and at San Bruno Mountain may or may not be of the same age. The greater maturity of the topography in the city hills and on San Bruno Mountain suggests, however, that these faults are both older than the San Andreas-Portola fault.

Folding.—This area has been folded into three blocks which are considered in the order of their importance.

Merced Block.—The area occupied by the Merced beds between Buri-Buri Ridge and San Bruno Mountain is in the form of a slight syncline; this is formed as the result of a block tilted toward the northeast by a thrust fault on the southwest side.

San Bruno Block.—Between San Bruno fault and Lone Mountain fault is the anticlinal fold, already noted and parallel to the San Bruno fault. Otherwise the whole block is simply tilted toward the northeast, the dips becoming steeper shortly before reaching the Lone Mountain fault.

Lone Mountain Block.—North of this fault line the folding is more complex. Parallel to the fault is a closely pressed syncline, called the Lone Mountain syncline, which can be followed from near Thirteenth and Market streets to the Calvary Cemetery, and, judging by the structure exhibited by the sandstone underlying the serpentine at the Presidio, it extends still further. Serpentine is exposed in different places, following the bedding planes of the sandstone, dipping toward the northeast or southwest, according to the side of the synclinal axis that it is on, showing that it is present as a true sill.

Major Folds.—Passing to the northeast of this syncline, the dip of the beds becomes less, averaging about 30° until Lafayette Hill is reached. From there they arch in an anticlinal dome to Russian

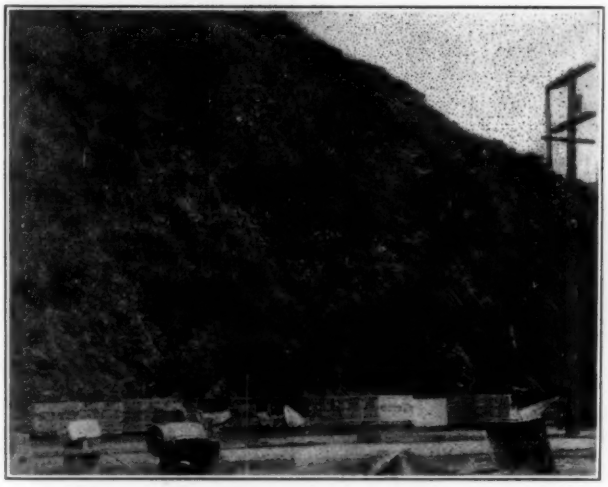


FIG. 14.

Bedding of shale in Telegraph Hill series; the exposure on Second street.

Hill and California Street Hill, in what is called the Lafayette Hill anticline. Between Russian Hill and Telegraph Hill is a syncline, the axis of which is closely followed by Montgomery avenue, which is called the Montgomery avenue syncline.

Minor Folds.—Lines of minor weakness are represented by a syncline through Rincon Hill, called the Rincon Hill syncline, an

anticline between the hill at Black Point and Russian Hill, the Black Point anticline, and an anticline between Rincon Hill and California Street Hill, called the Market street anticline. There

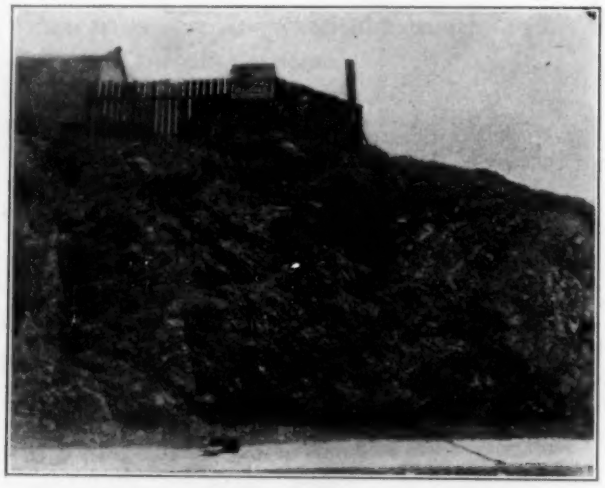


FIG. 15.

Local folding in Telegraph Hill sandstone; exposed in a street out on Jones street, near Vallejo.

FIG. 16.

Local folding in the jasper beds exposed at Golden Gate Park.

are besides these two small synclines, one of which is exposed at Lombard and Larkin streets, the other on Jones street near Vallejo street.

There are other minor lines of faulting but they are not of enough importance to be mentioned here.

A noticeable feature of the sandstone of the city is their jointing. These joint planes cut the rocks in many directions, without any apparent regularity, giving in exposed places such sharp, pro-

FIG. 17.

Serpentine of the Presidio sill resting upon a sandstone floor.

jecting, triangular faces, as to make it difficult or impossible to distinguish the original bedding planes. The pressure that produced these results in sandstone has not broken the jasper but merely thrown it into complicated folds.

Structure of Serpentine Intrusions.—All the serpentine areas of San Francisco peninsula are in the form of sills. The largest of these is the Presidio, and next are two nearly as large at the Potrero and at Hunter's Point. In the last two areas the hypersthene diabases have been intruded and have been broken up by the movements within the serpentine itself, during the process of hydration.

As a result of this breaking up the diabase outcrops are irregularly scattered through the serpentine areas. The sills at the Presidio and Potrero show the presence of two different serpentine intru-

FIG. 18.

A place in the cliffs north of the Presidio where the serpentine is intruded into the shales of the Telegraph Hill beds.

sions; whether they both occurred at the same time or at different times is not clear.

Sections through these different sills show their structural features plainly.

V. PHYSIOGRAPHY.

The main features of the topography of the northern end of the peninsula are controlled by the major faults, giving as a result two large blocks tilted toward the northeast, and one block with complex folding. The northwest-southeast trend of Buri-Buri ridge, San Bruno Mountain and the line of jasper hills across the city from the Cliff House to Hunter's Point is characteristic of the Coast Range ridges that are determined by major and minor faults and major folds. These features are plainly shown in the accompanying photograph of a relief map of the peninsula made by A. H. Purdue, of Stanford University.

FIG. 19.

Relief Map of San Francisco Peninsula by A. H. Purdue, 1894.

Merced Block.—Without considering the region south of San Andreas Lake in the Merced series, there is a tilted block, with terraces both older and newer than the faulting. This may be regarded as one large block that has many minor faults or smaller blocks of the same type as the large one. The largest of these faults, the one at Wood's Gulch, has determined the stream drainage at that point. Otherwise the drainage of the whole block is toward the northeast, or down the slope of the tilt. These streams have their heads in circular canyons, and which must represent a drainage system older than the Merced formation. The Franciscan series, forming the northeast front of the Buri-Buri ridge, are the cliffs of the pre-Pliocene beach, and the fact that the Merced series rests on the tops of these hills with almost a flat area shows that

FIG. 20.

A typical form of topography in the beds of the Merced series.

this is a pre-Pliocene terrace. The presence of the Merced series in place in the creeks and between hills of Franciscan sandstone indicates that the present drainage is controlled by the older drainage, the existing streams running down the submerged valleys of pre-Pliocene times.

Drainage.—The long, low valley between Buri-Buri ridge and San Bruno ridge is a slight syncline, the form of which is determined by the thrust block on the southwest side. It may have been the formation of this syncline that has controlled the drainage of the stream that once flowed through the basin now occupied by Lake Merced. This lake has been formed by the damming of the stream's mouth by a barrier beach; the bottom of the lake is now about ten feet below sea level.

San Bruno Block.—The physiography of the San Bruno block is apparently older than that of the Merced block and is determined mainly by structure.

Effect of Structure.—The next feature of note is the San Bruno thrust block. Along the southwestern side of the San Bruno range is a ridge of low hills capped with jasper. In the geological column these are probably within a few hundred feet vertically of the jaspers represented on Buri-Buri ridge. As these jaspers dip toward the southwest while those on Buri-Buri ridge (except near the fault zone) appear to dip toward the northeast there is the suggestion of a pre-Pliocene syncline, whose eroded trough has been the place of deposition of the Merced series. If the San Bruno fault is pre-Pliocene, as it seems to be, then the valley in which the Merced was deposited was an eroded syncline between fault blocks. The greater age of the San Bruno fault is shown by the more mature topography of that range as compared with the Buri-Buri country.

With one exception the streams of the San Bruno block drain northeast or southwest. In this exceptional case the stream turns at a right angle from a northeast direction and flows southwestward along the northeast side of the San Bruno mountains in a direct line with the Guadalupe Valley. The direction taken by this stream lends color to the suggestion that the Guadalupe Valley is a minor fault valley like Visitation Valley.

Drainage.—The anticline in the southwest edge of the San Bruno mountains shows its effect upon the topography at Ocean View where it has broken down. Heading near Ocean View is Islais Creek which runs by an indirect line to empty into the bay south of the Potrero. The drainage of this stream must have been guided by some previous topographic features that are not now

evident, though it follows the general northeast trend of the other streams. It is at present slowly filling the basin between the Potrero and Hunter's Point.

The hills through the center of San Francisco, at Golden Gate Cemetery, Strawberry Hill, San Miguel Hills, Bernal Heights and University Mound, owe their prominence to the large beds of jaspers that compose the major part of them. This jasper does not weather like a sandstone, but only breaks down slowly by mechanical means. The canyon through Almshouse tract, with its feeding streams, and the gap through Twin Peaks and Sunnyside addition are formed by the more rapid disintegration of the Silver Terrace sandstone than of the jaspers. The topography of this area in the heart of the city is controlled partly by the jaspers and serpentines and partly by the structure.

Lone Mountain Block.

Effect of Jaspers.—There is a low divide caused by the Lone Mountain fault crossing San Francisco from a point just northeast of Lobos Creek past Lone Mountain, to Hunter's Point. Parallel to this is a line of hills on which the cemeteries are located and Lone Mountain which have survived erosion because of their synclinal structure and the serpentine areas that have helped resist rapid weathering.

Effect of Serpentines.—The Presidio, Potrero, and Hunter's Point remain as noticeable features not because of the slowness with which serpentine alters, but because of the slowness with which it breaks down and is carried off by erosion. The reason the upper beds of sandstones and jaspers do not remain in places over these sills is because the large amount of movement that has taken place has so broken and crushed the overlying sandstone that erosion has been greatly facilitated.

Two small hills, one at Silver Terrace, and the other one and three quarter miles south of South San Francisco, owe their topographic relief to the intrusion of igneous rocks that have metamorphosed the tufaceous materials present to hard resisting greenstone.

Effect of Structure.—The divide between Lafayette and Russian

hills and Black Point and Russian Hill represents broken down anticlines while that between Russian and Telegraph hills along Montgomery avenue is a synclinal trough.

The flat in the business portion of the city with its sands and mud obscures the structure of the gap between California street hill and Rincon Hill. Rincon Hill being folded in a syncline parallel to the minor lines of folding, has the dip of the beds in a different plane from the dip of California Hill beds. The apparent solution is that Market street has been the direction of drainage of a stream passing between the two hills, through an eroded anticline.

There are no streams now draining this flat but if there were their drainage would be northwest-southeast along the axes of folding and at right angles to the direction of the streams on the tilted blocks.

The series of elevations and depressions to which this area has been subjected have not all left traces upon it. Various places around the bay show an old raised shore line. There are two terraces along Buri-Buri ridge—one at an elevation just a little above the floor of Merced Valley, the other at an elevation of five hundred feet. This last one is the pre-Pliocene terrace previously mentioned.[1]

VI. General Discussion.

Age of the Franciscan Series.—The age of the Franciscan series is not definitely and directly known from paleontological evidence, but must be arrived at indirectly by the age of the superimposed beds. The Franciscan series of sandstones and jaspers is very much broken up, metamorphosed and silicified by the dynamic movements through which it has passed. By this and by its constant macroscopic and petrographic characters it may almost always be recognized.

The conclusions of Dr. Fairbanks and Dr. Becker from their

[1] Lawson, A. C., Geology of the San Francisco peninsula. 15th Ann. Rept. U. S. Geological Survey, p. 464.

G. H. Ashley, Neocene Stratigraphy of Santa Cruz Mountains, Proc. Cal. Acad. Sci., Series 2, V, 354.

A. C. Lawson, Geomorphogeny of the Coast of Northern California, Bull. Dept. Geology University California, I, No. 8, p. 241.

work on the Franciscan series, are, that it is at least pre-Cretaceous in age, but how much older, is as yet unknown.[1]

Formation of the Merced Series.—The mode of formation of the Merced series seems from all the field evidence to have been a local deposition in an arm of the sea, or an outlet to the bay corresponding to the present Golden Gate. In the area south of this are large deposits of fresh water gravels that are considered by Dr. Arnold to be the fresh water equivalent of the Merced series. If this is true and these fresh water gravels represent a fresh water lake which emptied into the Pacific Ocean by way of the Merced outlet, then there should be faunal evidence of the change from fresh to salt water forms. Work of the nature that would demonstrate the plausibility of this theory has never been attempted. There remains, however, the conclusion that this great thickness of Pliocene beds exposed at Seven Mile beach is a local deposit formed in one of the two ways suggested and undoubtedly not extending in any such thickness over the main San Francisco Peninsula.

Origin of the Jaspers.—The Franciscan jasper was considered by Becker as metamorphosed silicious shale,[2] and by Lawson as a deposit from submarine springs.[3] The wide spread extent of the beds shows it to be a true bedded deposit, as it is known to extend from near the Oregon line to Santa Barbara county.

The presence of radiolarian remains in the jasper also show it to be a marine deposit. These fossils do not prove that the jaspers are composed of radiolaria but show that it is similar to present-day deep sea deposits. The agencies that have metamorphosed the sandstones have probably helped in the secondary silicification of the jaspers.

There is another possible origin for the large beds of jaspers in the Franciscan series and this is suggested by similar beds in later deposits. The siliceous Miocene shales resemble very closely the jasper beds under discussion except that they do not show so much folding and distortion. These Miocene shales are diatomaceous

[1] The Pre-Cretaceous Age of the Metamorphic Rocks of the California Coast Ranges, American Geologist, IX, 153. Monograph XIII, U. S. Geological Survey, p. 211.

[2] Monograph XIII, U. S. Geological Survey, p. 106.

[3] A. C. Lawson, 15th Ann. Report U. S. Geological Survey, p. 440.

deep sea deposits, altered since the time of their deposition. It is reasonable to assume that the older jasper beds may have been formed similarly to those of the Miocene age whose origin is known.

The fact that remains of diatoms do not show in slides of the jaspers does not prove that they were not there originally. These jaspers are mostly amorphous silica and must have passed through a stage of solution and re-deposition from their original form so that all traces of diatoms might easily be lost.

This hypothesis is worthy of consideration because of the large deposits of siliceous shale that we have in California; and it is more reasonable to consider the older jaspers formed after the same method of later shales, than to assume a different set of conditions and different organisms to have existed without any definite proof. The presence of radiolaria does not affect this either way because small amounts of any organism might be present with the diatoms and have their skeletons preserved.

The fact that in San Francisco we have a lignite and tuffs interbedded with the jaspers is significant. This lignite and tuff show conditions different from those under which the jaspers were deposited. The jaspers represent deep sea or at least quiet water conditions. The presence of lignite shows land conditions, while the jasper pebbles in the sandstone show that the Franciscan area was above the sea and that erosion had set in.

The tuffs present may mean that a period of volcanic activity was the cause of the change in the conditions under which the jaspers were being deposited and a return to land conditions as shown by the lignites. In this same sandstone are large and small pieces of shale, that resemble the shale of the series of rocks underlying the jaspers. This suggests that erosion went through the entire jasper bed and well down into the San Bruno series. There must be somewhere then, an unconformity in the series itself. The extent of this erosion interval is not known nor its place except that one area out of water must have been near the present city, as the pebbles are large and subangular. The second large bed of jasper shows the return of conditions favorable for the deposition of jasper.

Work through the area south of San Andreas lake and over the Santa Cruz quadrangle shows that the jaspers have been removed

from the southwest side of the San Andreas-Stevens Creek fault line but that remnants are still preserved on the northeast side. There is the possibility that the first movement along this fault line occurred at the time represented by the unconformity shown by the pebbles in the Silver Terrace sandstone. The area containing the unconformity is on the southeast side of this fault line, but the removal of the jaspers may be due to the erosion of the hills southwest of the fault during Pliocene times.

After the deposition of the jaspers conditions changed and the sandstones were deposited that appear in the northern end of the peninsula. The writer feels fairly sure that he has seen this Silver Terrace sandstone in other localities with the jaspers. Dr. Becker asserts that the granites underlie the Franciscan Coast Ranges. Then if this uplift took place, as suggested during the period of deposition of Silver Terrace sandstone the erosion would be greater in the Santa Cruz mountains on the southwest side of the San Andreas-Stevens Creek fault and would account for the appearance of the Montara and Ben Lomond granites.

Besides the large areas of jasper, there are small areas in various places throughout the Coast Ranges that do not seem to belong to the main beds. These may possibly be erosion remnants left by the removal of the larger masses, or it may be that the organisms forming the jaspers survive in colonies that form small lens-shaped masses. This latter suggestion receives support by evidence found at a place in the cliffs near Golden Gate Strait, where about six or eight inches of jasper appears in the sandstone several feet below the bottom jasper beds. The small bed appears to show the arrival of the first condition that allowed the development of the organisms followed by a period of slight change with sandstone and final settling to the quiet conditions in which the larger deposits were laid down.

The writer is of the opinion that both of these conditions may be found in any area where the jaspers occur.

Origin of the Serpentines.—The field evidence in San Francisco shows that the serpentines are formed by the alteration of olivine and pyroxene-bearing rocks. The large number of exposures has allowed the collection of an abundance of fresh specimens of the

rock. In the first part of the paper the petrography of these serpentines was given. There can be little doubt but that the serpentines elsewhere in California are of the same origin as these in this area; that is an alteration from olivine and pyroxene-bearing rock. Field observations at New Idria quicksilver mine and other places confirm this opinion.

The age of the serpentine intrusions on the San Francisco peninsula is not determinable, but field evidence elsewhere shows their age to be post-Knoxville and pre-Chico. In his work in the Coast Ranges Dr. Becker reports finding serpentine boulders in the bottom of the Chico,[1] which makes them pre-Chico. Dr. Fairbanks reports that on Grindstone Creek, Colusa county, the Knoxville shales have been metamorphosed for some distance by the intruded serpentine making the age post-Knoxville.[2] He also thinks that the unconformity between Knoxville and Chico may be due, in part, to the movements caused by the intrusion of these peridotite masses.

Origin of the Schists.—Whether the schists of the Coast Ranges are due to contact or regional metamorphism is a question that is still open. There is no evidence in the schists of the peninsula to prove this point definitely one way or the other. The schists occur both with and away from the serpentines. The quartzose glaucophane schist, described earlier in the paper, seems a result of dynamic rather than of contact metamorphism.

In connection with the formation of schists from contact with serpentines it may be said that the fact that sandstone taken from contact with the serpentine shows no noticeable metamorphism indicating that the action of the serpentine is not very great. If the schists were formed by regional metamorphism they might be formed along lines which would then be the places where the serpentines could be most easily intruded.

VII. The Earthquake of April 18, 1906.

Since the preparation of this paper there has occurred in California, and especially in this district, a seismic disturbance of unusual violence, resulting in the destruction of much property and a

[1] Monograph XIII, U. S. Geological Survey, p. 186.
[2] Fairbanks, American Geologist, IX, p. 161.

PROC. AMER. PHIL. SOC., XLVI. 185D, PRINTED JULY 15, 1907.

small loss of life. Inasmuch as this area is directly affected, a few remarks, of a general nature, are appended regarding the relations of the general geologic structure to the earthquake.

Relations to Structure.—As shown in the chapter on structure the northern end of the peninsula has its main features determined by three faults. The largest of these is the San Andreas-Portola fault which is one of the main lines of weakness in the Coast Ranges. The earthquake is supposed to have been caused by the movement along this old fault line. This disturbance was felt violently from Eureka, in northern California, to southern San Benito county. This is along the northwest-southeast line of valleys, continuous with Santa Clara Valley. Parallel to the fault zone the many towns in these valleys seem to have felt the earthquake with approximately equal intensities. Crossing the fault zone, at right angles, in a northeast direction, there seems some slight movement along a parallel line of weakness passing down through San Francisco Bay by Alviso, and southeastward, but there is no plain proof of this movement. The intensity decreases rapidly, going eastward from the fault, toward the San Joaquin Valley.

Movement along the San Andreas-Portola Fault.—The movement along the San Andreas-Portola fault line is quite apparent and consists of a thrust of the Merced block from three to eight feet toward the southeast, along the direction of the fault, with a slight downthrow, perhaps an average of twelve inches on the southwest, the first movement being the more important.

Intensity.—In San Francisco the general intensity was slightly less than that in some of the smaller towns near by. Substantial structures in that city were only slightly injured, broken chimneys and small cracks being the usual destruction. A considerable number of old and poorly made buildings fell with a slight loss of life compared with the population of San Francisco. The small number of deaths, however, was due to the hour at which it occurred. Disastrous fires broke out immediately and caused loss of life much larger than would have resulted from the earthquake, and with a loss of property that was excessively large in proportion to the damage done by the earthquake.

Effect.—In certain localities, between Lafayette Hill and the

cemeteries, on the north side of Russian Hill, in the district south of Market and in Mission valley near Eighteenth street, the intensity seems to have been greater than in other places through the city. Houses were completely demolished, car tracks twisted and broken, and water pipes bent.

Relations to Soil and Rocks.—In the first two districts mentioned the damage is due to the settling and sliding of sand on the hillsides. This is best shown near Steiner and Union streets, where crescent-shaped cracks appear in the street. In one place a house set on the hillside moved forward, down hill onto the sidewalk.

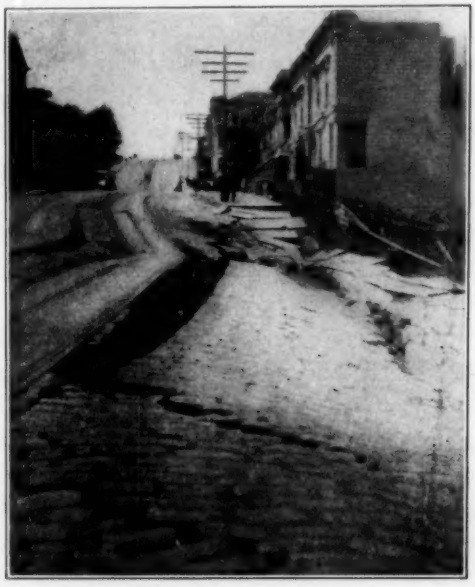


FIG. 21.

Union street near Steiner, showing the effect of a landslide caused by the earthquake.

In the other areas the buildings damaged stood mainly upon filled ground or recently formed loosely set soil. On Valencia street, where the greatest damage was done, a hotel that sank into the ground was upon material that had filled an old creek channel. The area directly around was also intensely disturbed, due, perhaps,

to the loosening of the soil by the circulation of waters made necessary by the filling of the old stream channel. The area on Howard street shows merely what happens when houses are on a landslide, as this is nothing more or less than a small, low angle landslide. These low angle slides are common in the soft Merced beds and at one place, near Mt. Olivet Cemetery, the soft wet æolian sand flowed several hundred yards down hill at a low angle, damaging the power house and carrying a lumber pile along with it. It is evident that the places that suffered most were those that stood upon loose sands or soils.

Other districts on the Franciscan rocks did not suffer so much and two areas especially, the Potrero and the Presidio, though offering no large buildings for comparison, seem to have suffered least. It is supposed that the reason for this is that the serpentine, with its many slickensided faces, has taken up a large part of the movement.

Along the San Andreas-Portola fault line the fissure formed by the movement may be seen plainly until it reaches the serpentine of Las Pulgas sill, where it almost disappears, but reappears plainly upon the southeast side of the serpentine. This fault line along which the movement took place in causing the earthquake may be plainly traced from Mussel Rock to Spring Valley lakes at Crystal Springs and on toward the southeast. It has the appearance of an irregular plowed furrow with occasional side furrows. The general downthrow cannot be observed continuously and persistently, but occasionally local variations of even as much as four or five feet occur, crevices being opened from a few inches to a few feet in one spot. The lateral thrust is not always apparent on the ground, but it may be clearly seen in the broken and offset fences across the fault. Various measurements of the slippage gave an average of three feet, but as much as eight and a half feet has been found near Woodside, San Mateo County.

Movements Along the San Bruno and Lone Mountain Faults.—The other two fault zones of the San Francisco peninsula, the Lone Mountain and San Bruno faults, show no discernible movement, and the intensity in the city of San Francisco shows no relation to these or any other structural features. In the area mapped the part that seems to have suffered most is in the soft Merced beds

near Baden. The cemeteries just north of that place show considerable evidence of the intensity of the shock. Holy Cross Cemetery suffered most, as much as seventy per cent. of the monuments having been overthrown, while many others turned or slid upon

FIG. 22.

A bend in the tracks of the South San Francisco car line near Baden.

their bases. Most of the monuments overthrown fell in a northwest or southeast direction and those that were twisted moved toward the southeast. All have not fallen in these directions, however, for the remaining fallen monuments lay in almost every possible direction.

Local differences in intensity are common and are shown, for example, by the fact that without any apparent reason Cypress Lawn had but a slight loss in comparison with Holy Cross Cemetery, which adjoins it, and which has the same soil.

At South San Francisco, several miles east of Baden, the movement does not show the same intensity as is seen in the Merced Valley. This is especially noticeable from the fact that the six or seven

brick chimneys were not thrown down, though some of them were cracked. These are within a very short distance of the San Bruno fault zone, and had there been any movement along that fault the intensity at South San Francisco would have been much greater.

The beds of the Merced series near and north of Mussel Rock are cracked, fissured and faulted in every direction. The Pliocene section along Seven Mile beach has been so altered by landslides

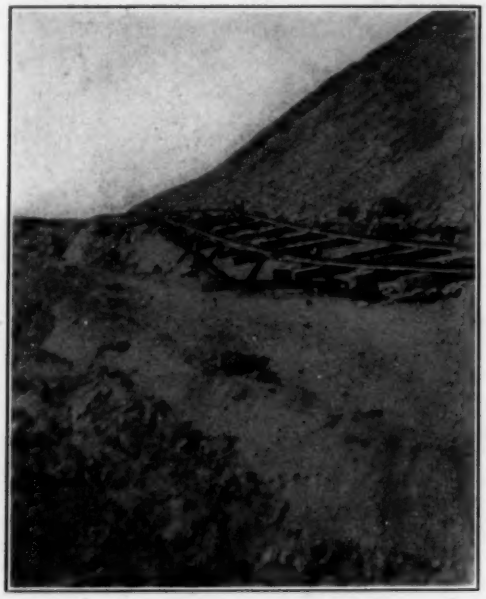


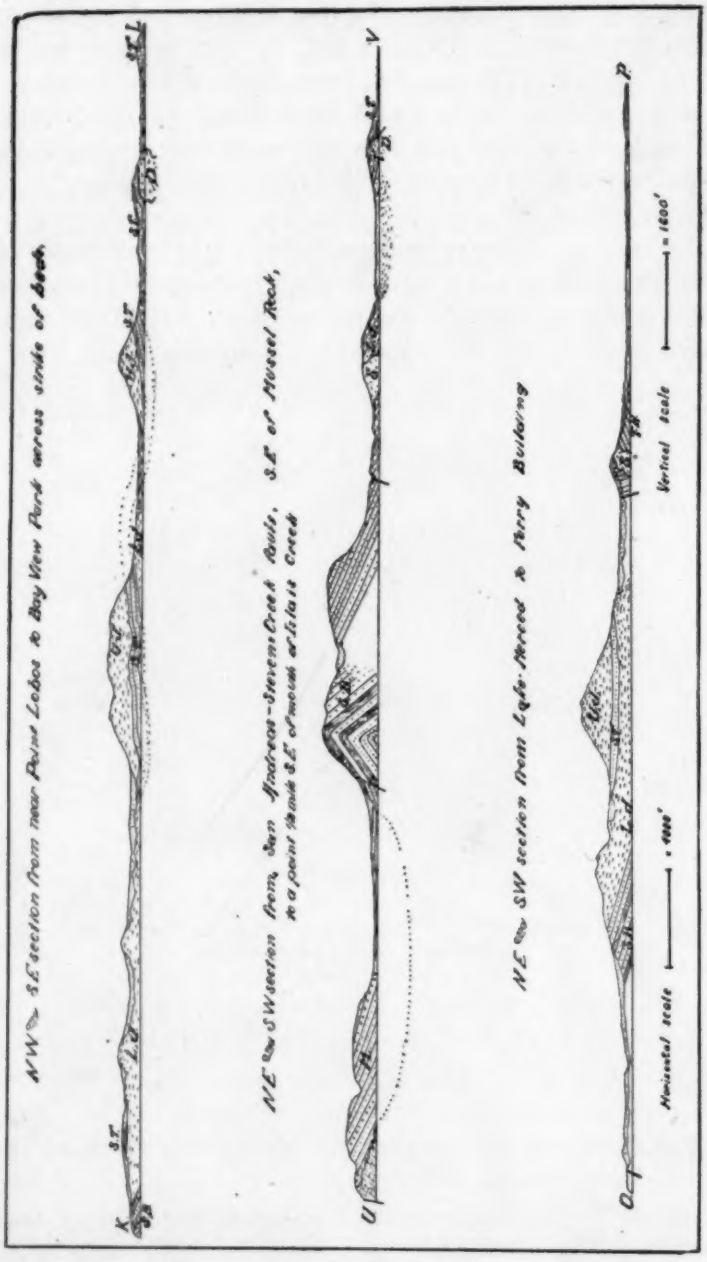
FIG. 23.

Effect of the earthquake along the road bed of the Ocean Shore Railway; three miles north of Mussel Rock.

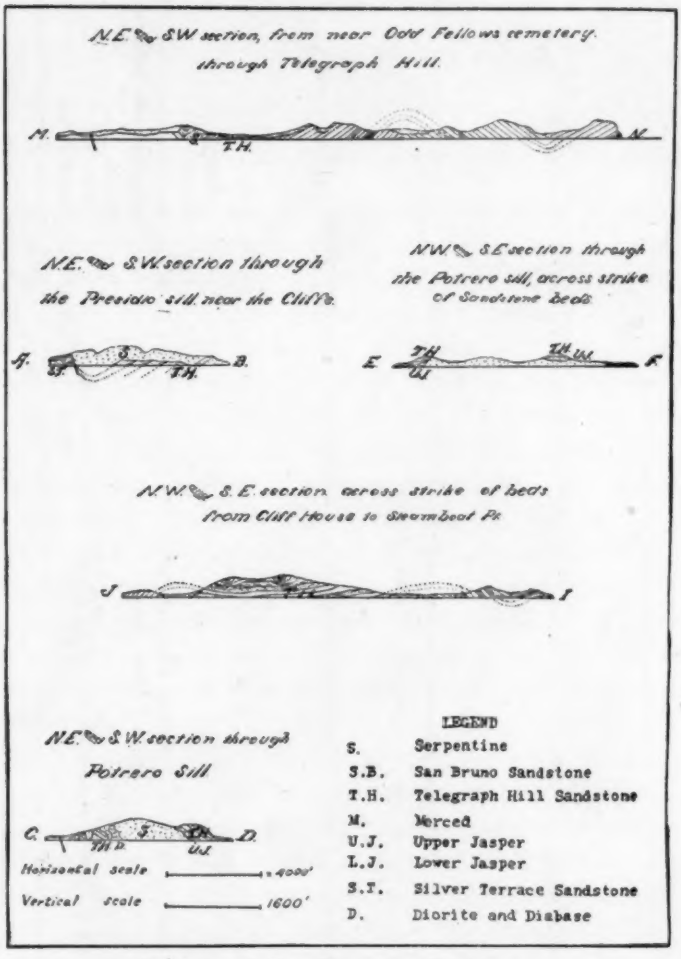
that it is hardly to be recognized. There is a tendency here for everything to slide into the ocean, even as far as four or five hundred feet from the cliff's edge. The road bed of the Ocean Shore electric railway line was seriously damaged along this bluff. Through Wood's Gulch and southeast of there along the fault line, landslides occur on both sides of the canyon, and long cracks cut across the hills just above the Chinese cemetery, showing that this fault is directly related to the main fault and probably formed at

the same time. The cracks in the hills southwest of the Chinese cemetery are almost in a direct line with the fault and may indicate a slight movement. The fact that these cracks are not continuous, so that they may be easily traced through Wood's Gulch to the ocean, leads to the belief that they are merely due to the settling or to the beginning of large landslides on the hill tops.

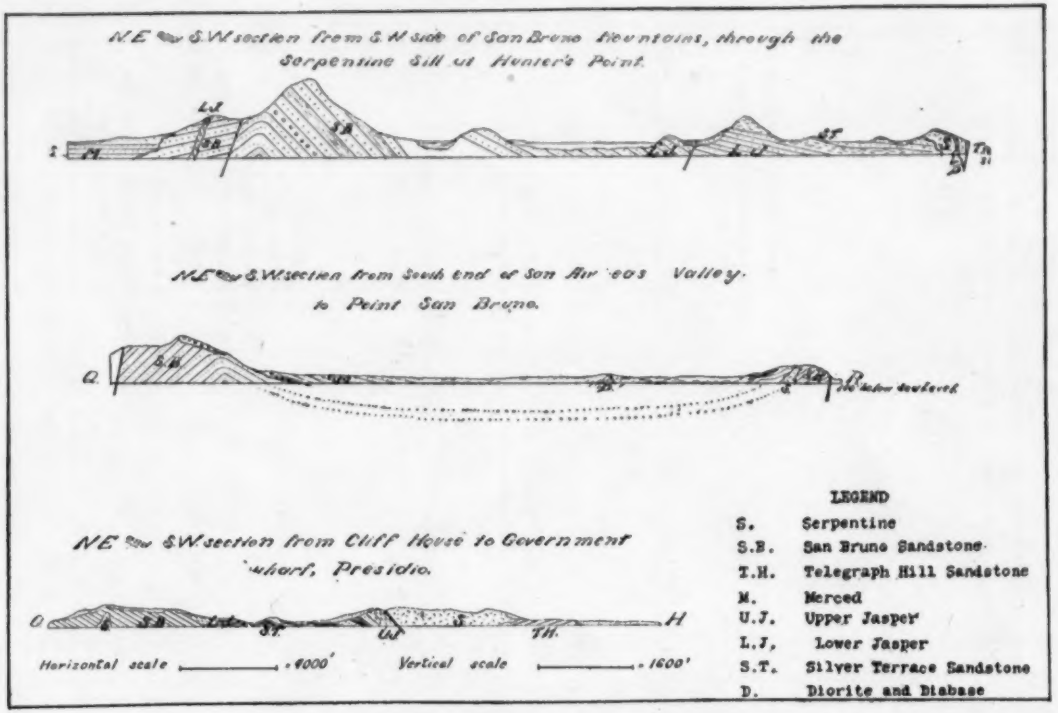
Movements of the adjoining Blocks.—The southwest side of the main fault line seems to be almost entirely free from cracks and fissures, though there are many and large landslides. The general evidence is that the intensity on this southwest side of the fissure zone was about the same as it was on the northeast side.


NW & SE section from near Point Lobos to Bay View Park across ridge of Hunters Point
NE & SW section from San Andreas-Stevens Creek Rails, S.E. of Merrel Rock, to a point 1/2 mile S.E. of mouth of Islais Creek
NE & SW section from Lake Merced to Ferry Building
Horizontal scale 1 = 4000'
Vertical scale 1 = 1000'

Sections of San Francisco Peninsula.



Sections of San Francisco Peninsula.


N.E. & S.W. section from S.W. side of San Bruno Mountains, through the Serpentine Sill at Hunter's Point.
N.E. & S.W. section from South end of San Mateo Valley to Point San Bruno.
N.E. & S.W. section from Cliff House to Government Wharf, Presidio.
LEGEND
S. Serpentine
S.B. San Bruno Sandstone
T.H. Telegraph Hill Sandstone
M. Merced
U.J. Upper Jasper
L.J. Lower Jasper
S.T. Silver Terrace Sandstone
D. Diorite and Diabase
Horizontal scale 4000'
Vertical scale 1600'

Sections of San Francisco Peninsula.

THE CATHODIC PRECIPITATION OF CARBON.

By WILLIAM BLUM and EDGAR F. SMITH.

(*Read January 4, 1907.*)

(Contribution from the John Harrison Laboratory of Chemistry.)

Some years ago[1] one of us (S) called attention to the electrolytic precipitation of iron, by the current, from citrate and tartrate solutions. In doing so, mention was made that on dissolving the deposited metal "in dilute, cold sulphuric acid a strong odor of hydrocarbons was perceptible." Later,[2] reference was again made to this fact and conditions given, observing which, the contamination of the metal by carbon might be avoided. In electro-analysis, the question of the contamination of metals by carbon, if the metals have been precipitated from organic electrolytes, has been quite freely discussed. However, the contamination in nearly all instances has been regarded as a result of carelessness in manipulation and may be avoided.

During the past summer we made observations, on the conduct of certain organic acids under the influence of the current, which seem of value, hence a brief account of them is submitted in this communication.

To begin, it was tried to ascertain the degree of reduction of oxalic acid at the cathode. The gasometric method was called into use, *e. g.*, a comparison of the volume of hydrogen evolved in the cell, with that liberated in a voltameter in the same period. It soon became evident that this procedure would not be delicate enough to detect any such reduction. However, while occupied in this way with an ammoniacal tartrate solution, a black deposit made its appearance on the cathode. When held in the flame it burned off completely from the platinum plate. The latter had an area of 100 sq. cm. Several actual trials may be here introduced. Thirty-seven

[1] *Am. Chem. Jr.*, 10, 330 and *Jr. Analyt. and Applied Chemistry*, 5, 488.

[2] Smith's "Electrochemical Analysis," 3d edition, p. 100.

and one-half grams of tartaric acid were dissolved in water, neutralized one-half with ammonia, then diluted to a liter. Portions of this solution were electrolyzed at a temperature of 60° C. The anode was a platinum spiral suspended in a porous cup. The cathode was the foil to which reference has been made. A current of one ampere and twelve and one-half volts acted for a period of two hours. A black deposit showed itself on the cathode. It burned off in the flame. In another experiment, with conditions like those just mentioned, discarding, however, the cup, there was no deposit on the cathode, but the solution was deep yellow in color. Again, in electrolyzing a portion of the ammonium tartrate without the porous cup, but surrounding the anode with a muslin bag, at the ordinary temperature, with a current of 4 amperes and 6 volts, there was a very considerable deposit, black in color, on the cathode. It burned away, with the exception of a mere iridescence, when held in a flame. In another experiment, fifteen grams of tartaric acid were neutralized with ammonia, diluted to 150 c.c. and electrolyzed at 60° C., for four hours, with a current of 4 amperes and 6 volts. The anode and cathode had both been weighed. The cathode became coated with a grayish black deposit. The anode sustained a loss in weight and only one-third of the cathodic deposit was carbon, the remainder being platinum, which had come from the anode.

Upon substituting a solution of citric acid (70 grams to the liter) and electrolyzing at 70° C., for three hours, with a current of one ampere and sixteen volts, a heavy black deposit separated on the cathode. It was not affected by hydrochloric acid. It burned away completely in a Bunsen flame. The electrodes were separated by a porous cup. In other experiments a muslin bag surrounded the anode. This bag had previously been well soaked in caustic soda. The usual black cathodic deposit was obtained. It burned away completely on heating. On digesting this deposit with chromic acid, carbon dioxide was obtained and recognized by its reaction with lime water.

Another trial is worthy of notice. In it a half normal solution of ammonium citrate, made alkaline with ammonia, was electrolyzed for a period of five hours with a current of 4 amperes and 6 volts. The anode was protected by a muslin bag. The solution

rapidly took on a yellow color, a distinct odor of acetamide was evolved and a black deposit appeared upon the cathode. It both burned on heating and generated carbon dioxide with a chromic acid mixture. It may be added that the solution was not heated from without as it developed a great deal of heat during the passage of the current.

Similar results were obtained on electrolyzing a like solution with out a diaphragm.

Other experiments were as follows:

1. Five grams of sodium citrate and one gram of citric acid were dissolved in 150 c.c. of water and electrolyzed at 60° C., for five hours, with a current of 4 amperes and 11 volts. There was a brass-like deposit on the cathode. It weighed 0.0018 gram, while the anode had lost 0.0014 gram.

2. Fifteen grams of citric acid, neutralized with ammonia and diluted to 150 c.c., were electrolyzed at 60° C., for four hours, with a current of 4 amperes and 6 volts. A grayish black deposit separated on the cathode. It equaled 0.0014 gram, which represents carbon. The anode lost in all 0.0103 gram in weight.

In the many trials made, the solutions gradually acquired first a pale yellow color which in turn passed to brown and at times almost black without becoming turbid. However, it must be said that solutions of ammonium oxalate, ammonium formate, ammonium acetate and ammonium succinate did not yield black deposits to the cathode. In solutions of ammonium lactate and benzoate they appeared as readily as in tartrate and citrate solutions.

This deposition of carbon upon the cathode is extremely interesting. In 1896, Coehn (*Z. f. Elektrochemie* (1896), p. 541) called attention to the fact that when carbon was made an anode in the electrolysis of sulphuric acid, the latter became at first yellow, and by prolonging the experiment, dark red and reddish brown in color. If this meant a solution of carbon the latter must presumably be in the form of ions, *e. g.*, in a form directable by the current. It must be in a form, which, as it does not decompose water, would appear at the anode. With these thoughts before him, Coehn electrolyzed sulphuric acid of varying concentration with an anode of carbon and a cathode of platinum. The result was a splendid deposition of carbon on the cathode. It burned away completely on

heating and gave carbon dioxide when acted upon with a chromic acid mixture. In later experiments, Coehn was able to determine, in the electrolytic way, the equivalent of carbon and found it to be 3.

Turning to our observations with tartaric and citric acid, it must be that these are broken down at the anode, during electrolysis; that the carbon thus liberated from combination in these acids enters aqueous solution as a hydrate of which the carbon is cation, and this, under influence of the current, passes in its ionic form to the cathode just as a metal, in some salt, does under similar influence. When, therefore, iron is deposited from a citrate or tartrate electrolyte, the carbon ions wander with the iron ions to the cathode, and there an alloy of iron and carbon appears. This alloy, on treatment with dilute sulphuric acid, generates hydrocarbons. Very little, if any, of the carbon deposited with iron is graphitic. It is chemically combined. Just as zinc and copper, from certain electrolytes, separate as brass, so do the carbon and iron separate as an alloy from the electrolytes which have been under discussion.

The conclusions warranted from the experiments here noticed and many others like them are:

1. Carbon is deposited on the cathode from solutions containing tartaric, citric, lactic and benzoic acids. This is particularly the case if a stationary anode be used along with high current density.

2. From solutions like those in 1, where high current density is employed, platinum will dissolve from the anode and be precipitated in part upon the cathode.

UNIVERSITY OF PENNSYLVANIA.

Stated Meeting January 18, 1907.

President SMITH in the Chair.

The following papers were read:

"Pennsylvania at the Jamestown Exposition, illustrated by the Lincoln Migration," by PROF. MARION D. LEARNED, which was discussed by Mr. Richard Wood, Prof. Cheyney and Prof. Leslie W. Miller.

"Reproduction, Animal Life Cycles and the Biological Unit," by PROF. THOMAS H. MONTGOMERY.

Stated Meeting February 1, 1907.

President SMITH in the Chair.

The decease was announced of Sir Michael Foster, F.R.S., on January 29, 1907, æt. 71.

PROF. EDWARD P. CHEYNEY read a paper on "The Roman Wall in Britain."

Stated Meeting February 15, 1907.

President SMITH in the Chair.

The following invitations were received:

From the Chicago Historical Society inviting this Society to be represented at the commemoration of the fiftieth anniversary of its incorporation on February 7, 1907, and Prof. A. A. Michelson was appointed as the Society's delegate on the occasion.

From the Seventh International Zoölogical Congress inviting the Society to be represented at the Congress to be held in Boston on August 19–23, 1907.

From the University of Upsala inviting the Society to be represented at the celebration of the two hundredth anniversary of the birth of Carolus Linnaeus on May 22d and 23d next. Dr. William W. Keen was appointed to represent the Society at this celebration.

The following communications were received:

From the Chancellor of the Smithsonian Institution announcing the appointment of Dr. Charles D. Walcott as Secretary of the Institution to succeed the late Samuel Pierpont Langley, deceased.

From the University of Aberdeen acknowledging the Society's congratulatory address on the occasion of its Quatercentenary.

From Mr. John H. Harjes, of Paris, presenting two large bronze plaques, and on motion the following minute was unanimously adopted:

Mr. John H. Harjes, with great and generous kindness, has presented to the Philosophical Society two *bas reliefs* commemorative of historic incidents in the life of Benjamin Franklin. One represents his reception by the King of France, the other commemorates the signing of the Treaty of Paris. Both are originals, of

which copies are upon the pediment of the statue of Franklin recently presented by Mr. Harjes to the City of Paris.

In accepting these beautiful examples of a difficult art, this Society returns its heartiest thanks to Mr. Harjes for his thoughtful generosity, and assures him of its thorough appreciation of the manner in which he has enriched France and America with appropriate gifts. Such acts of liberal patriotism promote mutual sympathy and amity among nations.

The American Philosophical Society will prize these gifts as enduring ornaments and choice possessions, and upon its walls they shall forever tell their story of the beneficent labors and unending fame of its illustrious founder.

The decease was announced of Prof. Dmitri Ivanovitch Mendeleef at St. Petersburg on February 2, 1907, æt. 73.

Dr. David L. Edsall read a paper on "Occupational Poisoning," which was discussed by Profs. Goodspeed and Smyth, Mr. Goodwin, Dr. Keller and others.

Stated Meeting March 1, 1907.

President Smith in the Chair.

Letter of acceptance of membership was received from Prof. August Weismann.

An invitation was received from the Board of Control of the Michigan Agricultural College inviting this Society to be represented at the celebration of the fiftieth anniversary of the institution on May 28–31 next, at Lansing, and Dr. William Powell Wilson was appointed to represent the Society thereat.

Dr. Allen J. Smith presented a paper on "The Mosquitoes as Bearers of Diseases," which was discussed by Doctors Cleemann, Harshberger, A. E. Brown and Conklin.

Stated Meeting March 15, 1907.

President Smith in the Chair.

The decease was announced of C. Percy La Roche, M.D., at Rome, on March 12, æt. 73.

Dr. Lightner Witmer read a paper on "Clinical Psychology," which was discussed by Mr. Owen Wister, Prof. Conklin, Dr. Frazer and Mr. Witmer.

Stated Meeting April 5, 1907.

President Smith in the Chair.

Invitations were received:

From the Royal Academy of Sciences of Sweden inviting this Society to be represented at its celebration of the 200th anniversary of the birth of Carolus Linnæus, at Stockholm on May 25, 1907.

From the Trustees of the United Engineering Society inviting the Society to be represented at the Dedication of the Building in New York given by Mr. Andrew Carnegie as a home for American Engineering Societies, on April 16th and 17th next.

These invitations were accepted and the President was requested to appoint delegates accordingly.

The decease of the following members was announced:

Albert S. Gatschet, Ph.D., at Washington on March 16, 1907, æt. 74.

Marcelin Pierre-Eugène Berthelot, D. ès Sc. at Paris, March 18, 1907, æt. 80.

John H. Brinton, M.D., at Philadelphia on March 18, 1907, æt. 74.

Dr. Martin G. Brumbaugh read a paper on the "Scope and Possibilities of a Municipal School System" which was discussed by Professors Houston, Miller, Haupt and Snyder.

General Meeting April 18, 19, 20, 1907.

April 18. Afternoon Session.

President Smith in the Chair.

The President opened the meeting with a brief address of welcome.

The following papers were read:

"Analogies Between the colonization of Ireland and Virginia,"

by PROF. E. P. CHEYNEY, of Philadelphia, which was discussed by Prof. Hewett and Prof. Cheyney.

"Early French Members of The American Philosophical Society," by DR. J. G. ROSENGARTEN, which was discussed by Prof. Smyth.

"The Influence of Imperceptible Shadows on the Judgment of Distance," by PROF. EDWARD B. TITCHENER.

"The Narrative of the 'Walking on the Sea,'" by PROF. WILLIAM A. LAMBERTON, which was discussed by Prof. Hewett and Prof. Lamberton.

April 19. Morning Session.

President SMITH in the Chair.

The following papers were read:

"Provisional Report of the Investigation of Foreign and Domestic Stage Micrometers," by PROF. MARSHALL D. EWELL.

"Chauvin (Chauvinisme-Calvin, Cauvin): Truth and Fiction in the Story of its Origin," by PROF. A. MARSHALL ELLIOTT, which was discussed by Professors E. S. Morse, Jastrow and Hewett.

"Charts Illustrating the Taxonomic Relations of the Monocotyledonous and Dicotyledonous Plant Families," by PROF. JOHN W. HARSHBERGER, which was discussed by Prof. E. S. Morse and Prof. Kraemer.

"Some Experiments with Plant Nutriments," by PROF. HENRY KRAEMER, which was discussed by Prof. Houston.

"Elizabethan and Jacobian College Dramas," by PROF. FELIX E. SCHELLING.

"The Bacteriology of Flax Retting," by GEORGE T. MOORE, Ph.D.

"Note as to the Measurement of the Action of Water upon Zinc and Lead," by PROF. WILLIAM PITT MASON, which was discussed by Prof. Elihu Thomson, Prof. E. J. Houston, Prof. Kraemer, Dr. Hulett, Mr. Willcox, Dr. Holland and Dr. Mason.

"New Results in Electro-Analysis," by DR. EDGAR F. SMITH.

"The Liver as the Seat of the Soul," by PROF. MORRIS JASTROW, JR.

Afternoon Session.

Vice-President BARKER in the Chair.

The following papers were read:

"The Progress of the Isthmian Canal," by DR. ELIHU THOMSON, which was discussed by the Right Hon. James Bryce and others.

"The Production of Synthetic Alcohol," by DR. HARVEY W. WILEY and HERMAN SCHREIBER.

"The Princeton Archæological Expedition to Syria," by HOWARD CROSBY BUTLER, which was discussed by Prof. Hewett, Dr. Heilprin and Dr. Butler.

"On the Transportation Crisis," by PROF. LEWIS M. HAUPT.

"The Association Theory of Solutions," by PROF. WILLIAM F. MAGIE.

"The Groups which are Generated by two Operators of Order Two and Four respectively, where Commutator is of order Two," by PROF. G. A. MILLER.

April 20. Morning Session.

Vice-President SCOTT in the Chair.

The following papers were read:

"Santa Cruz Typotheria," by W. J. SINCLAIR.

"The Stercornithes, or Fossil Birds of Patagonia," by MARCUS S. FARR.

"Restorations of Santa Cruz Mammals," by PROF. WILLIAM B. SCOTT, which was discussed by Prof. E. S. Morse.

"Distribution of the Condensation Nuclei in Dustful Air, with Remarks on the Methods of Counting Them," by PROF. CARL BARUS.

"On the Temperature, Secular Cooling and Contraction of the Earth, and on the Theory of Earthquakes held by the Ancients," by DR. T. J. J. SEE.

Executive Session.

President SMITH in the Chair.

The pending nominations for membership were read and the Society proceeded to an election.

Afternoon Session.

President SMITH in the Chair.

The tellers of election reported that the following candidates had been elected to membership:

Residents of the United States.

George Ferdinand Becker, Ph.D., Washington.

Charles Benedict Davenport, Ph.D., Cold Spring Harbor, L. I.

J. P. Crozer Griffith, M.D., Philadelphia.

Frank Austin Gooch, Ph.D., New Haven.

Herbert Spencer Jennings, Ph.D., Baltimore.

James Playfair McMurrich, Ann Arbor, Michigan.

Edward Laurens Mark, Ph.D., LL.D., Cambridge, Mass.

John Bassett Moore, LL.D., New York.

Francis Eugene Nipher, St. Louis.

Horace Clark Richards, Ph.D., Philadelphia.

John C. Rolfe, Ph.D., Philadelphia.

Allen J. Smith, M.D., Philadelphia.

Foreign Residents.

Baron d'Estournelles de Constant, Paris.

George Carey Foster, F.R.S., D.Sc., LL.D., Rickmansworth, Herts, England.

J. J. Jusserand, Washington.

John C. Kapteyn, Gröningen, Holland.

Sir William Turner, K.C.B., D.Sc., D.C.L., F.R.S.

The following papers were read:

"On Continental Development," by BAILEY WILLIS, which was discussed by Prof. Scott.

"On Jonah's Whale," by PROF. PAUL HAUPT.

"A Study of the Mean Temperatures of the Surface of the Moon, Earth, and other Planets," by PROF. CLEVELAND ABBE.

"Astronomical Photography," by PROF. E. E. BARNARD.

"Conservative Systems with Prescribed Trajections," by PROF. E. O. LOVETT.

"Comparison of Results of Latitude Observations at the Sayre Observatory, South Bethlehem, and at the Flower Observatory, Philadelphia, from September 30, 1904, to September 3, 1906," by J. H. OGBURN.

"Comparison of Results of Observations at the Flower Observatory for the years 1905 and 1906, with the Wharton Reflex Zenith Tube, and the Zenith Telescope."

"Two Remarkable Double Stars: (*a*) the Short Period Binary, Hough 212, and (*b*), the Stellar System, Krueger 60," by ERIC DOOLITTLE.

ON DISTRIBUTIONS OF NUCLEI IN DUST-FREE WET AIR, AND ON METHODS OF OBSERVATION.[1]

By C. BARUS.

(*Read April 20, 1907.*)

1. *Nuclei.*—The author remarks that the experiments described all refer to air, from which the ordinary or Aitken nuclei have been removed by filtration. The air is carefully kept saturated with water vapor, and examined in a plug-cock fog chamber by rapid exhaustion, partly without further interference, partly when acted on by the X-rays or the beta and gamma rays or radium, entering the fog chamber from without. The radium was sealed in an aluminium tube. Water nuclei when not themselves the subject of observation (as in § 6) were always scrupulously precipitated.

The kind of nuclei to be considered are thus, first, the vapor nuclei (colloidal nuclei) of dust free wet air, which are probably aggregates of water molecules; second, the ions produced by the presence of the radiant field, natural or artificial; third, water nuclei produced in dust free wet air by the evaporation of fog particles. A careful distinction is here to be made between water nuclei obtained from the evaporation of fog particles precipitated on solutional nuclei, on vapor nuclei, and on ions.

2. *Methods of Observation.*—The number of nuclei was computed from the angular diameter of the coronas of cloudy condensation. These were standardized, as shown in the author's earlier papers, by successive exhaustions, each of the same amount, the residual number of nuclei (after correction for subsidence) decreasing in geometric progression with the number of exhaustions. New experiments were deemed desirable for the present work and were carried out at great length.

To measure the angular diameters of the coronas the older

[1] Extract of certain investigations made by aid of a grant obtained from the Carnegie Institution.

method of a single point of light and a goniometer of special type on opposed sides of the fog chamber was first used. Figs. 2 and 3 give examples of these results.

Subsequently a new method was devised, in which two identical sources of light equidistant from the eye, were moved symmetrically toward and from each other, on a line parallel to the axis of the fog chamber. Observation consisted in placing the fiducial annuli of each of the two coronas in contact, by adjusting the lights at a distance S apart. A lever for this purpose is in the hands of the observer. The normal distance between S and the fog chamber being R and θ the angle of diffraction, $S = 2R \tan \theta$. The advan-

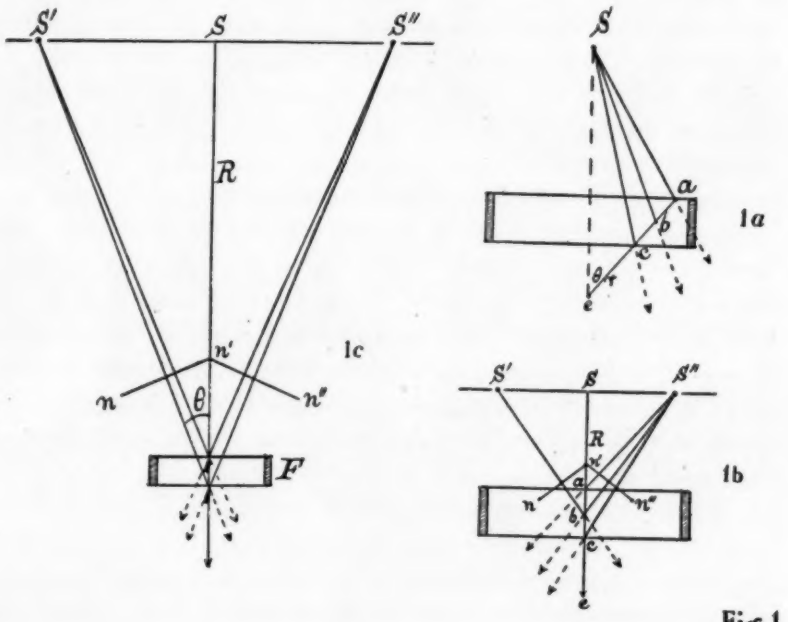


Fig. 1

FIG. 1*a*. Diffractions from a single source S from fog particles a, b, c, within the fog chamber, suggesting changes of the angle of diffraction to an eye at e. r is the radius of the goniometer.

FIG. 1*b*. Diffractions from two sources S' and S'' from fog particles at a, b, and c, within the fog chamber. Coronas nn' and $n'n''$ in contact.

FIG. 1*c*. The same drawn to scale. Fog chamber at F. Angles of diffraction shaded. Coronas nn', $n'n''$.

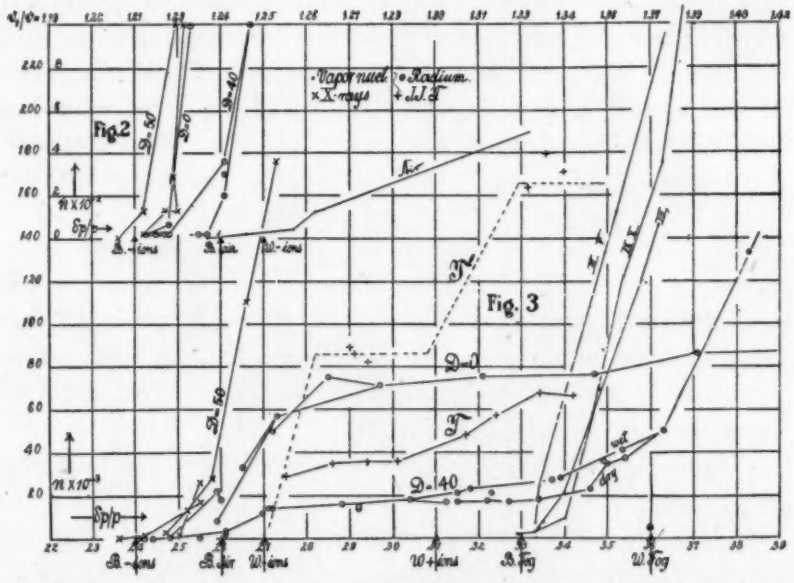
tage of this method of contact consists in this, that the observed diffracton takes place in the equatorial plane of the fog chamber; there is less obliquity of rays, and coronas of any size are observable (an essential condition since the angle for the large coronas approaches 60°), and both eyes may be used, placed all but in contact with the fog chamber. This diminishes the eyestrain and insures sharper vision. Lantern slides were shown giving all the details of this apparatus. The accompanying diagrams 1*a* and 1*b* indicate the differences of the old and new method and the latter is additionally elucidated in figure 1*c*.

3. *The Green Coronas.*—If the coronas be divided into two general types, those which have red discs or red primary annuli, and those in which the discs are green, the latter are convenient for comparison. In successive identical exhaustions they occur at regular intervals and among the larger coronas three successive series are particularly vivid, corresponding to fog particles whose diameters are $d_4 = .00052$, $d_3 = .00040$, $d_2 = .00023$ cm. These numbers may be regarded as in the ratio of 4, 3, and 2, and they suggest a first series with $d_1 = .00013$ as the highest type. The author has not been able to obtain this in any case whatever; but the red type of the first series is well produceable and is the first of a succession of diameters of fog particles, $d_1 = .00016$, $d_2 = .00032$, $d_3 = .00048$, $d_4 = .00064$, etc. The angular diameter of d_1 is about 60° showing the enormous size of the coronas in question. The occurrence of the first series is corroborated by the axial colors of the steam jet.

4. *Wilson's Conclusions as to Size and Number of Fog Particles.*—In the preceding section the conclusion was reached, that the smallest corona-producing fog particles must exceed the order of size, .0001 cm. Mr. C. T. R. Wilson believes that when "all diffraction colors disappear and the fog appears white from all points of view (adiabatic expansion 1.44) . . . the diameter of the drops does not exceed one wave length of light, or 50×10^{-6} cm." What Wilson refered to is probably the filmy disc of the red corona, of the order of $d_1 = .00016$ cm. It is therefore probable that Wilson's final greenish white color corresponded to about 10^6 nuclei, or that the filmy white implies two or three million nuclei, rather than

to 10^8 vapor nuclei per cubic centimeter as he asserts. Compare section 5.

5. *Distribution of Vapor Nuclei and of Ions in Dust-free Air.*—On March second the author gave a resumé of certain typical results to the American Physical Society. Distributions were there given in terms of an unsatisfactory expansion variable, $(\delta p - (\pi \rightarrow \pi_1))/(p - \pi)$, involving vapor pressure, π, as well as the drop in pressure, δp, from the atmospheric pressure p. In the present graphs these results and the new data specified will be given in terms of the relative adiabatic drop $\delta p/p$, as a more appropriate



FIGS. 2 and 3. Distribution of nucleation (n nuclei per cubic cm.) for different drops of pressure δp adiabatically from p, or volume expansion v_1/v. Series III to X were found with dust free air not energised at different times and temperatures. D refers to the distance of the radiant tube or X-ray bulb from the fog chamber. T and T' show the results of J. J. Thomson. W refers to Wilson's fog limits, B to those of the writer. Figure 2 is an enlarged detail of figure 3 refering in particular to the regions of ions.

variable for the plug-cock fog chamber. The adiabatic volume expansion is then

$$(v_1/v)^\gamma = 1/(1 - \delta p/p),$$

increasing with $\delta p/p$. Numerically $(v_1/v) - 1$ is not very different from $\delta p/p$.

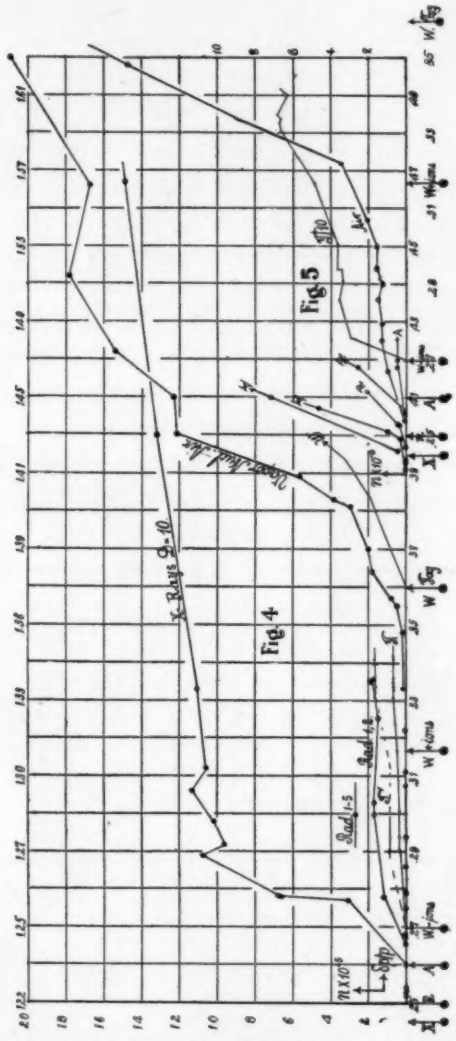
The charts contain an exhibit both of the older results and of new results. In the former the effect of rise of temperature in increasing the available nucleation to the extent of 5–10 per cent. per degree C., is marked. The earlier results are given in Figures 2 and 3.

In the new series (Figs. 4 and 5) and in case of vapor nuclei, the efficiency of the fog chamber breaks down above the green corona at about 1.5×10^6 nuclei per cubic centimeter; $\delta p/p = .41$; $v_1/v = 1.45$. Below this, the graph showing distribution and size of nuclei is well given, ascending definitely from about $\delta p/p = .31$, $v_1/v = 1.30$, which may be called the fog limit. Finally the region of ions appears as a well marked feature of the curve, extending from about $\delta p/p = .31$ to $\delta p/p = .262$, $v_1/v = 1.24$, where condensation begins (negative ions) for vapor nuclei. This is definitely below Wilson's point $v_1/v = 1.25$, for negative ions.

Exposed to the beta and gamma rays of Radium (10,000×, 300 mg.), the limiting ionization observed is below 200,000 nuclei per cubic centimeter; exposed to radium (10,000 × , 700 mg.), it is below 300,000 nuclei per cubic centimeter; but the condensation begins at $\delta p/p = .26$, or somewhat below $v_1/v = 1.23$, distinctly below the case for dust-free wet air.

The X-rays finally lower this condensation limit still further to $\delta p/p = .247$, or somewhat below $v_1/v = 1.223$, definitely below the point for the weak radium radiation. As compared with the curve for vapor nuclei the steepness of the X-ray curve with strong radiation, its almost sudden ascent is a further feature. It does not however, in my apparatus, get above the large green corona; *i. e.*, about 10^6 nuclei per cubic centimeter are caught at $\delta p/p = .29$, or $v_1/v = 1.27$.

One may notice, therefore, that the plug cock fog chamber puts both condensation points as well as the corresponding distribution of vapor nuclei, definitely *below* the values obtained by Wilson in his piston apparatus (marked *W* in the charts 2 and 3, 4 and 5). Moreover the march of the limits of condensation due to a given



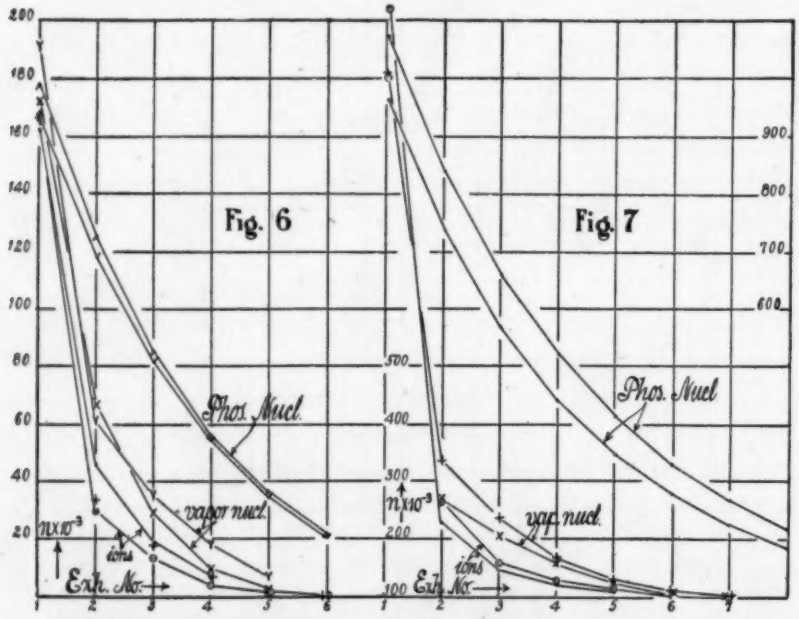
FIGS. 4 and 5. Results essentially like the cases of figures 2 and 3 but obtained by the method of two sources. The scale of nucleation is more compressed (ordinates $n \times 10^{-6}$). *X, R, A,* show the points at which condensation on ions produced by strong X-rays, by radium, and by natural radiation (dust free air) were observed. *W* refers to Wilson's results. Figure 5 is an enlargement of figure 4 in the region of ions or for low values of $\delta p/p$. *T* shows the results of J. J. Thomson.

radiation as compared with a maximum number of ions produced by that radiation is as follows;

natured radiation, air.....	$v_1/v = 1.24$	$n \times 10^{-3} = 1.5$
Beta and gamma rays used....	$= 1.225$	$= 100 - 150$
X-rays used.....	$= 1.220$	$= 10^5 \ldots 2 \times 10^6$

Since the intensity of radiation is as the square of the number of nuclei, an increase of the intensity of radiation from 1 to 10^4 and from 1 to 10^6 lowers the condensation limit ($v_1/v = 1.24$), 1.2% and 1.6%, respectively.

6. *Residual Water Nuclei. Behavior on Successive Evaporation of Fog Particles.*—Water nuclei are obtained by the evaporation of fog particles, on compression of the dust-free wet air in which they are suspended. One may expect them to differ with the nucleus or ion on which the fog particle is precipitated, and this is the case.



FIGS. 6 and 7. The ordinates show the nucleation (n nuclei per cubic cm.) obtained upon successive identical exhaustions and immediate evaporation, thereafter, of the fog particles precipitated. The abscissas give the number of exhaustions. The ions, the vapor nuclei of dust free air and phosphorus, or solutional nuclei are contrasted. In the latter case, removal by exhaustion is the only source of loss.

The best method of discriminating between water nuclei was found to be the successive evaporation of fog particles precipitated on the same nuclei under identical exhaustions, until the nuclei are wholly removed by the exhaustion and subsidence. The results may be exhibited in graphs, in which for about the same number of initial nuclei, the persistence of the corresponding water nuclei is shown by the number of nuclei which survive after successive evaporations, in case of phosphorus nuclei, vapor nuclei and ions. Compare figures 6 and 7.

In case of phosphorus nuclei, after z identical exhaustions, the number of nuclei n_z remaining is given by

$$n_z = n_1 y^{z-1} \Pi,$$

where n_1 is the initial number of nuclei per cubic centimeter, y the exhaustion ratio and the product, Π, the correction for subsidence; but if ions or vapor nuclei are used, an additional coefficient of loss x must be allotted to each exhaustion, so that

$$n_z = n_1 y^{z-1} x^{z-1} \Pi.$$

The following example shows this clearly.

TABLE I.

Ions.					Water Nuclei.				
z	$n \times 10^{-3}$	$n' \times 10^{-3}$	x	$(n'-n)/n$	z	$n \times 10^{-3}$	$n' \times 10^{-3}$	x	$(n'-n)/n$
1	166	166	1.00	0	1	172	172	1.00	0
2	29	117	.25	3.0	2	66	120	.55	.8
3	13	64	.45	3.9	3	29	77	.62	1.7
4	4	25	.53	5.7	4	9	42	.60	3.6
5	1	10	.80	8.5	5	2	12	.66	4.8
1	810	813	1.00	0	1	905	905	1.00	0
2	115	607	.19	4.3	2	166	673	.25	3.0
3	44	415	.48	8.4	3	103	473	.47	3.6
4	18	245	.52	12.5	4	57	319	.56	4.6
5	6	112	.47	18.5	5	24	201	.59	7.8

The exhaustion loss, x, is thus greater in the second exhaustion, or after the first evaporation of fog particles, three fourths to four fifths of the number of fog particles precipitated on ions vanishing, while one half to three quarters of the number of fog particles precipitated upon vapor nuclei vanish in the first evaporation, according as the initial number is smaller or greater. The exhaustion loss x is also greater for the case of precipitation on ions, as compared with the precipitation on water nuclei.

Since x is not constant the equation for the second exhaustion should read $n_1 y x \Pi_1$; for the third $n_1 y^2 x x' \Pi_2$; etc.

It will then be found that for ions

$x = .25$	$x' = .80$	$x'' = .76$, etc.
$x = .19$	$x' = 1.20$	$x'' = .62$, etc.

For water nuclei

$x = .55$	$x' = .70$	$x'' = .57$, etc.
$x = .25$	$x' = .88$	$x'' = .80$, etc.

data which are somewhat irregular, but accentuate the importance of the first evaporation.

Special experiments showed that the loss in question is specifically due to the evaporation, and not to time, as, for instance, the loss by diffusion of small nuclei would be. If the time interval between exhaustions is doubled or trebled, etc., there is no corresponding difference in the result.

7. *Decay of Ionized Nuclei in the Lapse of Time.*—If n be the number of nuclei per cubic centimeter, a the number generated per second by the radiant field, bn^2 the number decaying per second, $dn/dt = a - bn^2$. If the radiation is cut off t seconds before exhaustion, $a = 0$, $dn/dt = -bn^2$ or $1/n = 1/n_0 + b(t - t_0)$. Thus the relative nucleation may be found if b is known. If n_0/n is also known, given for instance by the above method of geometric sequences, the absolute nucleation $n_0 = ((n_0/n) - 1)/b(t - t_0)$ is determinable.

The result of this apparently straightforward method leads to grave complications, inasmuch as b is not constant but increases rapidly as the number of nuclei is smaller. Its value moreover is usually twice as large as the electrical coefficient $b = 1.4 \times 10^{-6}$. Thus in Table II,

TABLE II.

n	t	$b \times 10^6$	$b^1 \times 10^6$
83	0	2.9	3.8
38	5	2.1	4.1
27	10	3.3	5.7
14.3	20	4.2	13.4
9.0	30	3.5	
4.6	60	15.0	
1	120		

[1] By taking the first and fourth observations, etc.

which is an example chosen at random from many similar cases. The mean b (excluding the last) is thus .000,0045, at least three times as large as the electrical coefficient.

If but a part n of the nuclei are caught by the exaustion, n' escaping, $-dn/dt - dn'/dt = bn^2 + 2bnn' + bn'^2$. Hence if but $1/m$ of all the ions are captured, the coefficient of decay, b, found should be about m times too large as compared with the true value, or $dn/dt = -mbn^2$. But this fails to explain the increase of b with $1/n$, unless the nuclei grow smaller during decay (or virtually by loss of charge) and so pass beyond the scope of exhaustion. But this is improbable; the experiments show that b increases while the number of nuclei present decreases, no matter whether these reduced numbers of nuclei are due to weak radiation (generating but a few), or to low exhaustion (catching but a few), or to the decay of a larger nucleation (where only a few survive in the lapse of time). If $-dn/dt = -a + cn + bn^2$, where a is the number of ions generated per second by the radiation, cn the number independently absorbed per second and bn^2 the decay per second by mutual destruction, the integrated equation very fully reproduces the observed nucleations n, when $b = .000001$ and $c = .0356$.

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THE NARRATIVES OF THE WALKING ON THE SEA.

By WILLIAM A. LAMBERTON.

(*Read April 18, 1907.*)

The narratives of the walking on the sea are found in the first, second and fourth gospels, but not in the third: in the latter, however, this miracle is not merely omitted; there is what seems to me a significant substitute: or perhaps I should rather say a readjustment in the order of events. The passages are Mt. 14:22 ff., Mk. 6:45 ff., Jn. 6:16 ff. Cf. Lk. 9, 18–20.

In all three gospels the narrative follows the miraculous feeding of the 5000, this latter miracle also precedes the passage referred to in Luke. The miracle of the feeding occurs in a desert place on the shores of Lake Gennesaret; the walking on the sea in the departure thence by water, the general impression conveyed being that the boat crosses to the other side of the lake, though there are difficulties as to this. Before taking this up, we may enquire how the company came to this desert place.

In Matthew 14 we are told of the beheading of John the Baptist and in v. 12 we read of his burial by *his* disciples, who thereupon reported the fact (*ἀπήγγειλαν*) to Jesus, who upon this news received withdraws by boat to the desert place *privately*: hearing of his departure crowds from the towns follow him by land: the place, therefore, might be approached either way.

In Mark 6:30 Jesus's own disciples return from the mission on which he had sent them and report to him (*ἀπήγγειλαν*, the same word employed by Matthew) their experiences; whereupon he proposes that they go *privately* to a desert place and take a little much needed rest: this is done by boat: again crowds find this out and follow them *up by land* from all the towns, even *getting the start of them* (an important point).

In Luke 9:10 the apostles returned from their mission and recount (*διηγήσαντο*) all their adventures; hereupon (without reason

assigned) our Lord takes them with him and withdraws to "a desert place of a city called Bethsaida," or according to the better text "into a city called Bethsaida": in any case there is *no boat,* no crossing of the lake; the place is apparently *in* Bethsaida (its territory, of course) on the *west shore*: this at once raises the question, as to which scholars are not at one, whether there was really such a second Bethsaida; for Bethsaida Julias was on the east shore. The crowds notice the withdrawal and follow: again, how is not said.

In John 6:1 we read: Thereafter (a quite indefinite note of time) Jesus departed *across* the sea of Galilea, and a large crowd followed him, because they saw the signs he had wrought upon those that were sick.

The disagreement of Matthew with all the others is very noticeable and is emphasized by the word *ἀπήγγειλαν* which appears both in his account and in that of Mark as well as by the difference of subject—John's disciples in Matthew, Jesus's disciples in Mark. To be noted also is the fact that the story of John's taking off immediately precedes both in Matthew and Mark, but in the latter is detached from any connection with what follows; while in Luke what precedes is a parenthetical account of Herod's perplexity because of the news he had begun to hear of Jesus: "Herod said: John I beheaded: but who is this," and also (which is significant, as we shall see) the speculations of others: 'John has risen from the dead'; "Elias has appeared"; "one of the ancient prophets has risen again." In John's account this feature of John the baptist does not appear: no reason at all is assigned for our Lord's withdrawal with his disciples.

Now we come to the getting away from the "desert place": We will take Mark's account first, 6:45: Instantly he *compelled* (*ἠνάγκασε*) his disciples to get into the boat and go ahead *across the lake* to Bethsaida (in Luke they were in or near Bethsaida), and leave him to dismiss the crowd: Then, having dismissed the crowd, he went away *into the mountain to pray.* At a late hour they in their boat were in the midst of the sea and he was on the land. They were having a hard time (he saw them) with their rowing, for the wind was against them. About the fourth watch of the night (3 a. m.) he approached them, walking on the sea.—So far

Matthew and Mark agree, and John differs only in giving Capernaum, instead of Bethsaida, as the goal of their sail.—From what direction does he approach? From behind or from in front? A question of some importance: Matthew gives no indication, nor, perhaps, does John, but Mark implies very clearly that the approach is from behind; for he goes on to say ἤθελε παρελθεῖν αὐτούς. They see him, take him for a spectre and cry out in fright: he quiets them with a word and gets into the boat, wereupon the wind fell (Matthew has added before this the episode of St. Peter's attempt at walking on the water). They were quite beside themselves with astonishment: οὐ γὰρ συνῆκαν ἐπὶ τοῖς ἄρτοις, for their heart was hardened. They push on till they get across and land. Now what does οὐ γὰρ συνῆκαν ἐπὶ τοῖς ἄρτοις mean? As it stands and where it stands it is, I think, quite meaningless: it was evidently thought to mean something; and indeed, as we shall see, did mean something: it is in fact, I believe, a part of the original tradition which has got misplaced and so lost its meaning; for, really, it has none at all here. There is, of course, no objection to taking συνῆκαν absolutely; any verb in Greek may be so used; but then the context must make the application clear, as it does not in this case. And ἐπὶ τοῖς ἄρτοις, what shall we do with these words? It has been said that the sense is: the miracle of the feeding should have taught them a lesson that would have prevented all surprise at the walking on the water, but that this lesson had not been learned: but this looks like a desperate attempt to explain the inexplicable; and observe here that Matthew's story of Peter's attempt at imitating the feat quite contradicts this interpretation. I may say, here, that while I believe συνῆκαν genuine, but misplaced; I also believe that ἐπὶ τοῖς ἄρτοις should be τὰ ἐπὶ τοῖς ἄρτοις, for, as we shall see, what the disciples failed to understand was *what followed the feeding of the 5000*. If ἐπὶ τοῖς ἄρτοις be taken as equivalent to περὶ τῶν ἄρτων, as they may, the words are still out of place.

Looking back at Mark's account, we observe that Jesus *hurried his disciples away* with a view to dismissing the crowd: there seems no rationally assignable reason for this method of action. Then our Lord goes up into the mountain to pray: at last we have come to something that is suggestive. Jesus's praying is only thrice re-

corded in Mark: at his first day's work in Capernaum: here; and in the garden of Gethsemane: the first and last mark critical moments. Matthew has this instance and that in Gethsemane: critical moment this last. Luke has mention of Jesus praying at his baptism; at his choosing the twelve; at the Messianic confession; at the transfiguration; when he teaches his disciples to pray: all of them, each in its way, critical moments: there is besides solitary prayer in 5:16, which may be, though it is not clearly so, a critical moment. We may then conclude that the present moment was such a crisis in our Lord's history; just such a moment as would remain fixed forever in people's minds, though (for that very reason) the circumstances might come to be confused and would be very likely to be exaggerated; and with the tendencies then and there prevalent this exaggeration could not help taking the form of miracle, not absolutely invented, however, but springing out of misunderstanding of attendant facts. This will become clearer, if we can, as I think we can, discover the nature of the crisis. The phrase *οὐ γὰρ συνῆκαν* expresses really the attitude at the time of the disciples in the face of this crisis: they did *not* understand it: perhaps, then it is no wonder that Mark did not either.

Let us look at Matthew. All is as in Mark barring three things: (1) Jesus has no thought of passing them: (2) St. Peter will try to walk on the water too (here is exaggeration palpably setting in): (3) So far from showing any misunderstanding or unbelieving wonder, the disciples rather adore the Lord as he enters the vessel and cry aloud "Truly thou art the Son of God." Does not this give us a hint of the critical event, which in the confused tradition that came to Mark had been lost?

But let us look further. Luke has nothing of this walking on the sea, but he has before the feeding of the 5,000 the speculations (Messianic in tendency) of various unnamed persons connected with Herod's court and perhaps outside it; and then after it comes (9: 18–20) a record without note of time or place of an event that by Matthew and Mark is given at a later date and in a definite place, viz. at Cæsarea Philippi. And this event is nothing but the Messianic confession made by St. Peter in the name of all the disciples. Compare this with the words just quoted from Matthew, and the

conclusion seems inevitable that the critical event that is at the bottom of the whole narrative, the event which Mark lost and Matthew put in in an unintelligent way, was the confession of the Messiahship of Jesus. Yet were both Matthew and Luke, as well as Mark misled here: for this was the very thing (had Mark only known it) that the disciples "did not understand"; whereas in Matthew and Luke (though there are great differences) they do seem to have understood it. Matthew's mistake is in putting this confession in the mouths of his disciples; Luke's in antedating the scene at Cæsarea Philippi, with suppression, necessitated thereby, of the name of the place.

The account in John may help us out here (6:14). After the miracle of the feeding the *crowd* said: "this is truly the prophet, he that is to come (Cf. Matthew 11:3 when this phrase is used of the expected Messiah) into the world." Jesus saw they were for coming and seizing him "to make him king, and so he withdrew into the mountain in solitude." He does not dismiss the crowd, but flees from their premature intent of proclaiming him Messiah in their own sense. Separation even from his disciples for the moment seemed demanded by the critical situation: he had discerned the purpose of the crowd and left before they had time to declare it; at the same time in a plausible way he got his disciples away from the contagion of the crowd, to which they might have succumbed and thus interfered with his wiser and more prudent plans. The disciples embark and start *across* the lake for Capernaum (not Bethsaida, as Mark has it). After dark there came a high wind and the sea rose. They had made 25 or 30 stadia when they saw Jesus walking ἐπὶ τῆς θαλάσσης: as he neared the ship, they got scared; but he quieted them: *they* wanted (ἤθελον) to take him aboard and instantly their boat was at the shore they were making for. In Mark (alone) we read Jesus wanted (ἠθέλεν) to pass by them (and did not); in John *they* wanted (ἤθελον) to take him into the ship, but we are *not* told that he got in. This identity of the verb (ἤθελεν-ἤθελον), though with a different reference, can hardly be accidental. This one word seems to point to identity of original and to the misunderstanding and its cause. Jesus did *not* enter the ship: therefore he did *not* walk on the sea: he was walking on the

shore, on the beach close to and toward the waters edge. *ἐπὶ τῆς θαλάσσης* may perfectly well mean this, though it *may* have the other meaning also: but only this interpretation seems to cover all the facts as given by John. They have rowed, they don't know precisely how far: they guess 25 or 30 furlongs, but are nearer shore, as the event proves, than they had supposed. Jesus had been alone in the mountain (he had not stayed to dismiss the crowd, therein Matthew and Mark are mistaken, he was too eager to get away from their dangerous presence): after dark, towards morning in fact, he makes his way down to the shore at the point where he looked for his disciples to land (Matthew and Mark both speak of his seeing the boat from the land), thus imitating in the reverse direction the movements of the crowds, when they followed him (and got ahead of him, we remember) to the "desert place." The disciples see him as he approaches the shore and comes nearer to them: they may have thought that he was actually beyond the shore line (they probably did) and coming out to them: they are frightened and, when quieted by his assurance that it is he, their master, they wanted to get him on board; so they put on a spurt in their eagerness and before they knew it (having miscalculated their distance probably in the dim light) they were at the land and there was their Lord. This same conclusion has been reached (but on insufficient grounds) by J. Weiss in his Life of Christ and by Edwin A. Abbott in his Johannin grammar solely on syntactical grounds. The confusion in the tradition, shown by the accounts in Matthew and Mark and the omission by Luke, entirely due to a misunderstanding of what happened, arose in all likelihood from the fact that Jesus hurried (*ἠνάγκασε* in Matthew and Mark) his disciples away, and hence they were perplexed—did not understand *τὰ ἐπὶ τοῖς ἄρτοις* = what followed the miracle of the feeding. The wonderful scene they had just witnessed, the abrupt way in which their master fairly drove them into the boat and made them push off, put them into a state of mind where senses and memory at once were likely to play them false, and this seems to have happened.

The clear result is, that there appears to have been a risk of Jesus being seized and proclaimed as Messiah in what may be called the temporary and political sense; this was to run counter to

his purposes, hopes and beliefs and must be somehow escaped. That a critical fact occurred at this time the tradition as given in the synoptics recognized, but the nature of it was missed and the miracle came in to fill the gap; the way being opened for it by the strong, but confused impression made by the whole series of events on the minds of the eyewitnesses, whose senses in the excitement deceived them or were misinterpreted afterwards. Their confusion remained on record in the enigmatical *οὐ γάρ συνῆκαν* of Mark, and the real fact in the transposition of the Messianic confession of Luke.

The significant words about which the whole story crystallized would seem to be: *ἠνάγκασε — ἀπῆλθεν εἰς τὸ ὄρος — αὐτὸς ἦν ἐπὶ τῆς γῆς — εἶδεν αὐτοὺς —ἐπὶ τῆς θαλάσσης — ἤθελεν (ἤθελον) — οὐ γὰρ συνῆκαν — ἐπὶ τοῖς ἄρτοις.*

THE EARLY FRENCH MEMBERS OF THE AMERICAN PHILOSOPHICAL SOCIETY.

By J. G. ROSENGARTEN.

(*Read April 18, 1907.*)

In 1768 Buffon was elected, the first Frenchman to become a member of this Society, and thus the first of a long list of his countrymen chosen for this honorable distinction. In the same year Du Simitiere was elected, still remembered as a local antiquarian, and he brought some French spirit into this Society,—he was diligent in his attendance and active in adding to its collections. In those colonial days naturally the ties with the mother country were very close, and in the same year General Gage and Sir Wm. Johnson were elected. Buffon, Linnæus, elected in 1769, and Benjamin West were presented with the Society's publications. In 1772, Le Roy of the Academy of Sciences in Paris was elected. In 1775 Franklin, President in the chair, presented books by several French authors, Decquemare, Dennis, Rozier, Condorcet, Daubenton, Dubourg, Le Roux, Raynal, Lavoisier, and they were elected. "The calamities of war" interrupted the meetings and they were not resumed until the British had evacuated Philadelphia.

After the meetings were resumed, Gérard de Rayneval, the first French Minister sent here was elected, and a bound volume of the *Transactions* was presented to him, and received with expression of his intention to forward the interests of the Society in France. He attended the meetings and agreed to forward thanks to Buffon for the gift of his works. The example thus set was followed by the election of his successors, Ternant, Luzerne, Adet, Otto, Genet, Fauchet, and in later years of Hyde de Neuville and Poussin—all French Ministers here. In 1781 La Fayette and his companion in arms Chastellux were elected, and Barbé de Marbois, the French Consul in Philadelphia, whose death the Society mourned in 1837,—in his ninety-fifth year. In 1784 Vergennes, and in 1785 Guichen,

Lieutenant General of the French 'Naval Armies,' were elected. Later Cabanis, Cadet de Vaux, Le Veillard, friends of Franklin during his long stay in Paris, were elected, and St. Jean de Crevecœur, long a resident in this country,—his books made it known abroad, and have recently been republished for their interest and value.

In 1789 Brissot de Warville was elected,—he had travelled in this country and urged French colonies in its western lands,—later he came here as a refugee from the French Revolution, but returned to France and was guillotined. Moreau de St. Mery, a refugee from the French West Indies, was elected in acknowledgment of his contributions to the Society's *Transactions*,—he settled here, opened a book store, was a frequent attendant at the meetings and helped to secure exchanges with French scientific societies.

In 1796 Lerebours and Talleyrand, and in 1800 Dupont de Nemours, and in 1799, Volney—all exiles from France—were elected. Later Lesseps, Consul of France in Philadelphia, and father of the builder of the Suez Canal, was elected, and in 1823 Joseph Bonaparte, and in 1824 his nephew Charles, both exiles after the fall of Napoleon, and long residents here, were elected, with other Napoleonic exiles, Real, Miot de Melito, and in 1829, Hyde de Neuville, the Bourbon minister here.

After the alliance with France, the Society voted that "ten pounds of the best kind of raw silk produced in Pennsylvania be sent to Lyons, there to be wrought in the most elegant manner, and presented to her most Christian Majesty as a mark of very high respect." In 1783 Jefferson moved and Reed seconded and it was ordered that Rittenhouse should make an orrery to be presented to his most Christian Majesty. In 1784 La Fayette, by special appointment, entertained the members with an account of the invisible power called animal magnetism, lately discovered by Mesmer, and soon after Marbois presented the report of the Commissioners appointed by the King of France to investigate the subject.

In 1781 Rochefoucault, Charles, lecturer in experimental philosophy and aeronaut, and in 1791 Du Ponceau, aid to Steuben, and in 1796 Rochefoucault de Liancourt, known by his sympathetic volumes on his travels in this country, were elected. In 1797 Volney

was elected; he returned to France and became a member of the Institute, his book of travels was not nearly so kindly in its tone, and he spoke harshly of his countryman Brissot de Warville for advising Frenchmen to come here. Barbé de Marbois on his return to France was employed in the Foreign office and was an active agent in the sale of Louisiana,—his 'Memoir' was credited with securing Napoleon's approval of the treaty that ceded that vast region to the United States.

In 1789 Quesnay de Beauregard, who had served in the Revolutionary war, presented his elaborate Plan of the Academy of Sciences and Belles Lettres, established by him in Richmond, Va.; it was a very broad scheme for a sort of exchange bureau and clearing house of scientific and literary intelligence between the United States and France and other European countries,—the French Revolution put an end to it;—he was a grandson of Quesnay, one of the leaders of the French economists,—his son wrote on the Constitutions of Pennsylvania and Massachusetts, and his grandson was the prosecuting attorney against Boulanger.

Le Gaux was elected in 1789, no doubt in recognition of his efforts to establish vineyards at Spring Mills, near Philadelphia.—Du Ponceau, who was elected in 1791, began life as a student for the priesthood, but came here at the suggestion of Beaumarchais, as secretary and interpreter for Steuben,—he became a member and later a leader of the Philadephia Bar, president as well as a frequent contributor to the proceedings of the Philosophical Society, and was elected a member of the French Institute in recognition of his writings on Indian languages, etc.

Many of the French exiles found, as Pontgibaud, one of them, said, an ark of safety in Philadelphia, and most of those then or later famous, were elected; at one time so many attended that they addressed the society in French, and here at least there were representatives of all the conflicting elements of French politics, Royalists, Girondists, republicans of every opinion, and they met apparently in great harmony in these peaceful halls, discussing scientific questions. Dupont de Nemours had filled many important positions in France, had helped Vergennes negotiate the Treaty of Peace with Great Britain, was a leader among the economists of France,

and president of the French Constituent Assembly, and while his sons established in this country the business still carried on by their descendants, several of them became members too,—he returned to France and filled important posts. He wrote at the suggestion of Jefferson, an essay on Education in the United States, in which he presented a plan for primary, secondary and higher schools, colleges and universities.

With the nineteenth century began the election of many leaders of science in France,—Roume, Delambre, Destutt de Tracy, Lasteyrie, Michaux, Vauquelin, Deleúze, Pougens, Remusat. Money was subscribed by the Society toward the expenses of Michaux's western explorations, and later for a statue of Cuvier in Paris. Wm. Maclure, formerly a merchant of Philadelphia, after a long residence abroad, returned, bringing with him a corps of naturalists, to help him in a plan for a geological survey of the United States,—one of them, Le Sueur was elected a member in 1817; trained in the Jardin des Plantes in Paris, he contributed many papers to the scientific societies abroad and here,—joined Maclure in founding the Academy of Natural Sciences and was active in both bodies. Later he went with Maclure to New Harmony, Indiana, and continued his scientific studies in the then far west, and returning to Philadelphia, taught drawing, was a frequent attendant at the meetings of this Society, and at last returned to France, to take charge of the Natural History Museum of Havre, where he died in 1846.

In 1803 the National Institute of France promised, as successors of the French Academy of Sciences, to resume correspondence and exchanges, established by Franklin during his long stay in Paris. Franklin left by will of this Society, 91 volumes of the History and Transactions of the Royal Academy of Sciences of France, and after his death, it bought from his library many French scientific books, and by Hassler's aid, completed many of the serial publications of French scientific societies, which now form an important part of its large and growing collection of works of that kind.

At a later time at a meeting at which Joseph and Charles Bonaparte attended, they and Le Sueur and Du Ponceau spoke of the earlier days of frequent attendance of French members and visi-

tors. It was here that Talleyrand collected material for the papers he read after his return to France, before the Institut, in which he spoke in flattering terms of his stay in this country,—mentioning his asking a chance acquaintance, Benedict Arnold, not knowing him, for letters of introduction, and Arnold's reply that he was the only American who could not help him with his countrymen. Hyde de Neuville, a royalist exile, lived here for some years, after the restoration of the Bourbons returned to France, filled some important posts, then came back as French Minister,—was kept busy watching the Napoleonic exiles, some of them alarming him by their military colony in Texas, and wild schemes for a French Empire in Mexico, with a Bonaparte to reign over it;—he politely returned to Joseph Bonaparte a portrait of Napoleon found at the French Legation in Washington,—returned to France, was Minister of Foreign Affairs under Louis Philippe, and left an Autobiography full of incidents of his life here.

Later King Louis Philippe, A. Julien, Stanislas Jullien, Larrey, Roux de Rochelles, Guizot, de Tocqueville, Poussin, French Minister to the United States, Leverrier, Pouchet, Michel Chevalier, Brown Sequard, Elie de Beaumont, Milne Edwards, St. Claire Deville, J. B. Dumas, Verneuil, Claude Bernard, Lesquereux, Renan, Boucher des Perthes, Gasparin, Mariette, Carlier, Leon Say, Broca, Viollet le Duc, Claude Jannet, Paul Leroy Beaulieu, Rosny, Pasteur, Levasseur, Duruy, Nadillac, Taine, Berthelot, George Bertin, Maspero, Poincaré, Becquerel, Darboux, were among the representative Frenchmen of science and letters elected to membership in this Society, thus perpetuating the long roll of French members which began with Buffon. This goodly custom will no doubt long continue as a proof that the alliance of France and the United States, to which this country was so largely indebted for its independence, will be perpetuated by inviting to membership in this Society the leaders of French intelligence in every field of research.

In the collection of this Society there is manuscript by Mr. Samuel Breck, a member from 1838 until his death in 1862, in his ninety-first year, in which he gives his recollections of some of the early French exiles, members of this Society. He speaks of these too, in the volume of his "Recollections," published in Philadelphia

in 1877. He mentions the fact that Talleyrand, like others of his fellow exiles, notably Volney, took the oath of allegiance to the State of Pennsylvania. Talleyrand speculated in land and stocks, and made money, thanks to the help of William Bingham, then the richest man in this country. It is characteristic that although Talleyrand brought a letter from Lafayette to Washington, the President declined to receive him until he was about to return to France, to begin that diplomatic career which made him so conspicuous in European affairs for many years.

Mr. Breck also speaks sharply of Volney, who earned his living here by teaching, and his unfavorable opinion is confirmed by the contemporary report of an English visitor, Thomas Twining, who thought that Volney's temper was soured by his loss of power in France,—on his return he attained a position of importance and yet in his "Travels," said little that was kind of the country that had given him a safe refuge. This too was true of Brissot de Warville in his "Travels,"—but he, poor fellow, went back to France too soon, and ended his life under the guillotine.

Mr. Breck says that Rochefoucauld and the Orleans princes took their enforced exile very good naturedly. Chastellux, who had served under Rochambeau, as well as his comrade, Lauzun, and a later exile of a very different type, Brillat de Savarin, better known by his book on cooking than by his more serious work as a judge, all said kind things of the country and people who gave them shelter in their distress. Many of the French travellers who have visited and written about this country, were members of the Philosophical Society, and from its large and valuable library, drew much information for their writings.

The publication of the writings of Franklin, edited with fidelity by Professor Albert H. Smyth, one of our members, enables us to see in Franklin's vast collection of his papers preserved here, how largely he influenced and was in turn influenced by his French associates. Many of his friends in Paris were scientific men of great distinction and leaders of public opinion there and many of them became contributors by papers, gifts of pamphlets and books to this Society, and no doubt at his suggestion, were elected members, and thus became interested in its work. The example then of our

great founder and of the many notable Frenchmen elected members from his day on, may well inspire this Society to continue and increase its activity by electing other Frenchmen sharing in its task of promoting useful knowledge.

Note: At the General Meeting of the Society held April 20th, 1907, M. J. J. Jusserand, French Ambassador at Washington, and author of many valuable works, was elected a foreign member of the American Philosophical Society.

THE EFFECT OF IMPERCEPTIBLE SHADOWS ON THE JUDGMENT OF DISTANCE.

By EDWARD BRADFORD TITCHENER
AND
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(*Read April 18, 1907.*)

Some six years ago, an investigation was published under the above title from the Psychological Laboratory of the University of California.[1] Briefly stated, its thesis was that a motive to optical illusion, although so faint as to be wholly imperceptible to the observer, is nevertheless effective in the determination of judgments of visual distance. One is required to compare, under certain methodical conditions, the lengths of two contiguous sections of a straight line. To all appearances, the stimuli are perfectly simple: one sees, drawn horizontally upon a white background, a thick black line which is bounded and divided by three vertical black marks; and the problem is, in successive observations, to report upon the equality or difference of the two sections thus displayed. The peculiarity of the experiment lies in the fact that the stimuli are only apparently simple. In certain series, not known to the observer, the experimenter throws upon the white background angular shadows, disposed in such a way as to convert the two lengths of line into the two parts of the Müller-Lyer illusion. These shadows, be it repeated, are so faint that they are never, even under the greatest strain of attention, visible to the observer. Yet they have their due effect: the judgments of length of line prove to be subject to a constant error, whose sign, *plus* or *minus*, reflects the tendency of the motive to illusion.

This contention is, in itself, startling enough. A great deal has been written, of recent years, about the subliminal and the subconscious, and many wonderful things have been declared in their name. Where the phenomena are obscure, the definitions arbitrary,

[1] K. Dunlap, in *Psychological Review*, VII., 1900, 435 ff.

and the training and temperament of the writers markedly diverse, much variety of opinion will ensue, and dogmatism is altogether out of place. But the case now under consideration is unique.[1] It is asserted that in straightforward psychophysical method-work, done under strict conditions, the eye may be solicited by lines which it cannot see, the judgment warped by a motive which is neither in consciousness at the time nor ingrained by habit in the nervous system of the observer.

A principle so revolutionary—for the whole environment is full of subliminal influences, which experimental psychologists have systematically neglected!—must, one would think, be based upon unequivocal evidence. Hardly less surprising, now, than the conclusion itself are the numerical results which claim its acceptance. The standard length of line, throughout the experiments, was 25 cm. The errors of judgment ascribed to the illusion motive vary between the extreme limits of 1.05 mm. and 0.10 mm.[2] "The difference," as the author admits, "is slight; but," he adds, "we should hardly expect to get more than a slight effect from the shadows under the circumstances."[3] The effectiveness of an optical illusion, that is to say, stands in direct proportion to the clearness of contour of the figure shown. Is it not more reasonable to suppose that an illusion motive, if effective at all, will be effective at full strength? Or, at any rate, is not this alternative supposition worthy of experimental test?

It is, however, easier to accept a statement once made—especially if the content of the statement fall in with our immediate intellectual purpose—than critically to estimate the value of the evidence upon which the statement rests. And Dunlap's thesis has, accord-

[1] Dunlap finds a parallel to his own results in the experiments of C. S. Pierce and J. Jastrow on small differences of sensation (*Memoirs of the National Academy of Sciences*, III., i., 1884, 75 ff.). There is however, no resemblance whatever between the two investigations. As the latter has been discussed by G. E. Müller in 1904 ("Die Gesichtspunkte und die Tatsachen der psychophysischen Methodik") and by Titchener in 1905 ("Experimental Psychology," II.), and as it contains nothing which can invalidate the canons of psychophysical method, we leave it here out of account.

[2] Dunlap, *op. cit.*, 448. The figures given are: 0.62, 0.40, 0.17, 0.83, 0.18, 0.10, 1.05 and 0.72 mm.: an average of half a millimetre!

[3] *Op. cit.*, 450.

ingly, found its way, as matter of proved fact, into the current 'literature' of psychology.[1] This circumstance alone is a justification for the reopening of the whole question.

Apparatus and Method.

It is clear that the conditions of the experiment may be met in two different ways. Either the white background may be made translucent, and the shadows shown from behind by transmitted light; or the background may be made sensibly opaque, and the shadows thrown upon it from the front. Both forms of apparatus were employed by Dunlap: our own experiments, for reasons which will be given later, were performed only with an apparatus of the first type. In order that the two sets of results might be comparable, we at first set up this apparatus in accordance with Dunlap's description, and reproduced his method of work.

A sheet of white bristol-board, 58 by 72 cm., was mounted horizontally in a black wooden frame. Across the middle of the sheet was drawn a black line, 1 mm. in width, which was crossed at the centre by a vertical black line, 0.75 mm. wide and 17 mm. long. To the sides of the frame, at the level of the horizontal line, were fastened guides, in which ran small rods of blackened steel: the rods could be drawn in or out along the line, and were of course invisible against it. The inner ends of the rods carried vertical strips of black paper, 2 mm. wide and 10 mm. long. These strips, like that at the centre, extended equally above and below the horizontal line; and the three together marked off the two sections of that line whose lengths the observer should presently be called upon to compare. A mm. scale, attached to the frame above the rods, and a small marker on the rods themselves, made it possible to set the limiting strips, with accuracy, to any required position.

[1] We may mention G. M. Stratton, "Experimental Psychology and its Bearing upon Culture," 1903, 88 ff.; J. Jastrow, "The Subconscious," 1906, 417 ff.; J. B. Pratt, "The Psychology of Religious Belief," 1907, 20. Dunlap's results are accepted by M. Meyer ("Aus den Versuchsergebnissen geht mit Deutlichkeit hervor, dass auch in solchem Falle die Illusion stattfindet"), in *Zeits. f. Psychol. und Physiol. d. Sinnesorg.*, XXV., 1901, 266; by A. Meyer, in *Journal of Philos., Psychol. and Sci. Methods*, IV., 1907, 80 f.; by the anonymous reviewer in *Mind*, N. S., X., 1901, 281; and, although with more reserve, by J. Philippe, in *Rev. philos.*, 1901, 341. We are not aware that they have as yet been incorporated in any formal text-book of psychology.

. The shadows were cast by angular pieces of stiff black cardboard (angular magnitude, 60°; length and width of legs, 45 and 5 mm. respectively). One of these was fastened to the back of the sheet, its vertex coinciding with the centre of the central vertical line on the front. The other two moved in or out with movement of the limiting strips. The arrangement was simple: the rods carrying the strips were bent round, to the back of the frame, and there passed through guides placed at the level of the front guides and strictly parallel to them. The cardboard angles were attached to the inner ends of this second pair of rods, with their vertices at the centres of the strips. Whenever, then, the limiting strips were moved, their angles moved with them, and strip in front and angle behind maintained always the same relative position.

The apparatus thus constructed was set up on a table in a dark room. Its front surface was illuminated by two hooded incandescent lamps, placed symmetrically on either side and at equal distances from the sheet; its back surface was illuminated by a single hooded lamp, placed opposite the centre of the sheet. This third lamp was controlled by a rheostat, and all three were on the same electric circuit. The bulbs were of ground glass, and the light of the lamps was further diffused by sheets of tissue paper.

The procedure was now as follows. The observer, seated before the apparatus, was left in the dark for 15 minutes, in order that his eyes might be properly adapted for the experiments. The lights were then turned on, and the experimenter held up, directly behind the frame, a circle or a skeleton square cut from black cardboard. The intensity of the light at the back was slowly reduced, until the observer was just unable to detect the shadows cast by these figures. Or, rather, the reduction of the light was arrested at a point somewhat short of this: at the point, namely, when the observer declared that there might perhaps be a shadow there, on the white background, but that he could not possibly decide whether it was the shadow of a square or of a circle. We may say at once that the arrest of the rheostat at this point caused us some inconvenience in the experiments proper, since it not infrequently happened that the observer remarked, in the course of a series, that he thought he saw a shadow on the white sheet: in which case the

series was thrown out, and repeated later on. We wished, however, to give the subliminal shadows every chance to produce their effect, and were therefore content to run this risk of additional work.

Having regulated the intensity of the light behind the apparatus, the experimenter affixed the Müller-Lyer angles to the sheet and rods. The constant or standard line, which was placed as often to the right as to the left, was 25 cm. in length. The variable line was set, at the beginning of a series, to appear either as distinctly longer or as distinctly shorter than the standard; and the limiting strip was moved in or out, by steps of 1 mm. and at intervals of 15 seconds, until several judgments had been recorded of the opposite tenor to that with which the series began. Every series taken with the angles was paired with a precisely similar series taken without them.

The order of experimentation was, so far as possible, left to chance. Thus, the position of the angles for a given paired series, as open or closed, was determined by lot. There were as many series beginning with "longer" as with "shorter," but their distribution was also determined by lot. Finally, while the members of a paired series were always given together, chance was allowed to decide whether the shadow-series should precede the shadowless, or conversely.

The judgments of the observer referred always to the variable line, and took the form "longer," "shorter," and "equal" or "doubtful." The middle point of the region of doubt and equality was taken as the mean equality point of the single series, and this was compared with the mean equality point of the other member of the pair[1]. Five observers took part in the experiments: Mr. L. R. Geissler, Mr. C. R. Hugins, Professor T. A. Hunter, Mr. W. H. Pyle and Miss E. A. Smith. All except Mr. Hugins had had extended training in psychological observation.

[1] In the foregoing, we have closely followed Dunlap: *op. cit.*, 436 ff. The principal differences of procedure appear to be these: that we gave our observers a fairly extensive preliminary practice; that we allowed a period for adaptation of the eyes to the dark; and that we placed the standard line as often on the one side of the figure as on the other (for Dunlap, the standard was always on the left).

Experiment I.—What, now, of the results? Dunlap quotes no figures. He merely says that "a set was counted 'for' or 'against' the illusion according as the difference between the mean equality points was or was not in the direction which would correspond to the possible effect of the illusion-figure."[1] And he tabulates his results as follows:

Observer.	Paired Series.	For Illusion.	Against.	Neutral.
A	23	14	8	1
R	11	9	2	0
S	13	8	5	0

Nothing is here said of the magnitude of the illusion-effect. If, however, this point is disregarded, and our own results are treated as Dunlap prescribes, we obtain the following table:

Observer.	Paired Series.	For Illusion.	Against.	Neutral.
G	8	4	3	1
Hg	12	5	5	2
Hn	12	3	5	4
P	10	4	4	2
S	12	4	7	1

It is plain that the two sets of results are not in agreement. Since apparatus and method were practically the same, and care and skill in the conduct of the experiments may be assumed to be equal, we can only conjecture that the positive testimony of Dunlap's series is due to chance, operating on a small group of observations.

Experiment II.—It would, naturally, have been simply a matter of time to extend these series to a point at which the effects of chance should be ruled out. It seemed advisable, however, to modify the procedure. Dunlap himself refers to the experiments above reported as "preliminary to the investigation proper," and asserts that the apparatus was "not very satisfactory in its operation":[2] though he gives no details. We found two principal sources of error. On the one hand, we feared that the presence or absence of light behind the screen, as the change was made from shadow-series to shadowless, might influence the observer's judgment. We

[1] *Op. cit.*, 439.
[2] *Op. cit.*, 439, 436.

decided, therefore, to keep the illumination constant, and to remove and attach the Müller-Lyer angles as occasion demanded.[1] On the other hand, there can be no doubt that the direct pairing of two precisely similar series is methodically indefensible; the observer tends to say 'equal' or 'doubtful,' in the second series, at about the same point at which he passed this judgment in the first.

The method that would naturally be employed in an investigation of this sort is the method of constant-*R* as applied to the determination of equivalent stimuli.[2] We desired, however, to keep as closely as possible to the method chosen by Dunlap, and accordingly proceeded as follows. For each observer we made out a set of twenty-four single series. In eight series, the angles were used with the "illusion long" as the variable. In eight series, the angles were used with the "illusion short" as the variable.[3] In the remaining eight series, the illusion-angles were not used. On the basis of the previous experiments we selected eight different starting-points for these series, four lying well without and four well within the point of subjective equality. The order of the single series was decided by chance; the variable was shown as often on the right as on the left. The intervals between series were kept constant, so that the observer had no means of knowing whether or not the experimenter changed the apparatus. For the rest, the observations were taken and the calculations made as in the preliminary experiments.

The table shows the results obtained from five observers: the *G*, *Hg*, *Hn* and *P* of the former experiments, and Mr. R. W. Sailor, a trained observer.

[1] It must be remembered that, though the observers were not informed of the object of these experiments, and (with the exception of *P*) were unfamiliar with Dunlap's work, they nevertheless received a fairly definite suggestion from the preliminary tests with the circle and skeleton square. No one of them reported any difference in the appearance of the white background from series to series. Two, however, differentiated the series by the glow of light shed upon the table by the back lamp when this was turned on. We arranged black curtains to cut off this diffused light; but there was still a faint glow upon the walls of the room.

[2] Titchener, "Experimental Psychology," II., 1905, i., 104; ii., 258.

[3] Dunlap, *op. cit.*, 437. In Dunlap's use of the phrases, the reference is always to the left or standard segment of the line.

Observer.	Average Setting of Variable with		
	Illusion Long.	Illusion Short.	No Illusion.
G	249.8 ± 2.5 mm.	251.4 ± 2.8 mm.	250.1 ± 2.5 mm.
Hg	252.8 ± 1.8	249.5 ± 1.8	249.8 ± 1.4
Hn	251.7 ± 2.0	246.6 ± 0.9	249.2 ± 2.5
P	250.0 ± 0.9	250.0 ± 1.1	249.6 ± 2.1
S	250.0 ± 1.5	248.0 ± 2.2	250 5 ± 2.0

If the illusion motive is effective, the figures of the first column will be less, those of the second greater, than the corresponding figures of the third column. The observers *Hg* and *Hn* thus give negative results; *P* and *S* give one positive and one negative; and *G* alone gives two positive results. But a glance at the magnitude of the differences, as compared with that of the *MV*, shows the absurdity of drawing any conclusion of this sort from the results.[1]

Experiment III.—In view of the negative outcome of this second set of experiments, it seemed necessary to raise the question suggested in the introduction to this paper: the question whether an illusion motive, if effective at all, must not be effective at full strength. Have we any reason to suppose that a dim illusion-figure will produce a small effect, and a clear illusion-figure a marked effect upon the observer's judgment? We approached this problem as follows.

The horizontal line and its three markers were removed from the white bristol-board, and their place was taken by a length of fine black sewing thread. To render the shadows of the Müller-Lyer angles intensive, we placed three lamps behind the apparatus,

[1] The averages, as was stated above, have been calculated in Dunlap's way. We have submitted the figures to all the other forms of methodically permissible treatment known to us, and can discover no trace of the influence of the illusion motive.

Jastrow declares (*op. cit.*, 417) that if, after experiments with the Müller-Lyer figure, one proceeds to experiment upon the estimation of visual distances in Dunlap's way, *i. e.*, with "the shadow-strokes reduced to such a degree of faintness that the eye fails to detect their presence," the observer will judge "naturally with diminished confidence" as to the relation of the two lines. Why? If the shadows are not seen, how can the observer's confidence be diminished? He is simply called upon to compare two horizontal lines.—On the general question of 'degree of confidence,' see esp. G. E. Müller, "Gesichtspunkte u. Tatsachen der psychophysischen Methodik," 1904, 21 f.

and darkened the two lamps in front by curtains of black cloth. Under these conditions, the shadows stood out sharp and crisp upon the thread line. To render the shadows faint, we reduced the intensity of the single light at the back, as in the previous experiments, until the angles were barely perceptible. These faint shadows were, of course, stronger than the shadows of the earlier experiments. In the latter, the light was so far reduced that, at best, only shapeless patches of bright grey could be discerned upon the white background. In the present series, the shadows were still seen as angular strips of very light grey. At the same time, they were so faint that they frequently faded out, in whole or part, during the progress of a series. If, then, the efficacy of the illusion motive varies with intensity of stimulus, there should be a wide difference in the results of experiments carried out at these two extremes of the intensive scale.

As the illusory effect of the Müller-Lyer figure may decrease with practice,[1] we thought it well to secure the services of naive and untrained observers, in order that we might compare their judgments with the judgments of some of the trained observers already at our disposal. Experiments were made with two unpractised observers, Miss G. M. Fairlamb and Mr. G. W. Hau. Of *H*'s results we shall speak presently. The average effect of the illusion motive in the first eight series taken with *F* was

Shadows Weak.	Shadows Strong.
30.6 mm.	41 mm.

There was thus a distinct difference in favor of the stronger shodows. Nevertheless, the high value of the *MV* in the series with weak shadows, the length of time required for the passing of judgment in the critical zone, and the observer's complaints of the fluctuating character of the shadows, showed that the two series were not

[1] C. H. Judd, *Philosophical Review*, ix., 1902, 27 ff. Judd's law of decrease with practice is not universal, as is proved by the fact that the magnitude of the Müller-Lyer illusion-effect in the case of one of the writers (T) has shown a slight but constant *increase* with increase of practice. Cf. V. Benussi, "Zur Psychologie des Gestalterfassens," in A. Meinong's "Untersuchungen zur Gegenstandstheorie und Psychologie," 1904, 331 f. In general, however, we agree with Judd and F. Schumann (*Zeits. f. Psych. u. Physiol. d. Sinnesorg.*, XXX$_3$, 1902, 263 f.) that, with spontaneous reaction to the figure, practice tends to reduce the illusion-effect.

strictly comparable; we had made the weak shadows too weak for our direct purpose. At all events, the illusion-effect of 30.6 mm. with the weak shadows is a large effect, and it is hardly possible that the further weakening of the shadows, to the point realised in the previous experiments, should, if the illusion motive is effective at all, reduce this effect to a magnitude smaller than the *MV* of practised observers. To make assurance doubly sure, we took twenty-four series of experiments with *F* under the original conditions, and obtained the results:

Average Setting of Variable with		
Illusion Long.	Illusion Short.	No Illusion.
249 ± 2 mm.	249.7 ± 1.2 mm.	250.5 ± 1 mm.

That is to say, there is no evidence of any effect at all exerted by the imperceptible shadows.

F's practice was continued, until the magnitude of the illusion-effect was approximately the same for her as for our more practised observers. We finally obtained the following average values for the illusion:

Observer	Shadows Weak.	Shadows Strong.
F	9.1 mm.	12.7 mm.
G	12.1	10.3
P	11.1	16.9

It is an irony of chance that the observer *G*, whose results have so far been (in Dunlap's sense) accordant with the hypothesis of the influence of imperceptible shadows, should here give a larger illusion-effect with the faint than with the strong shadows.

The table is not altogether satisfactory, because the weak shadows were, throughout, fluctuating; we had made them a little too weak for comparative purposes. But the main point is clear: even on the very edge of imperceptibility, the weak shadows have an effect that is of the same numerical order as the effect of the strong shadows, and this with observers whose judgments show no influence of imperceptible shadows.[1]

[1] The figures of the table represent the average value of the illusion-effect as drawn from 16 methodically planned series, in 8 of which the variable gave the "illusion long," and in 8 the "illusion short." The smaller values obtained for the illusion-effect with shadows weak, in the cases of *F* and *P*, are accounted for by the fact (attested both by measurement and by introspection) that in a few series the tips of the shadows were so faint that the illusion motive was disregarded by the observer.

Experiment IV.—*H*'s results were, from the first, radically different from those of *F*. Whereas *F* showed an initial illusion-effect of about 35 mm., *H*'s first two series, with the shadows strong, gave a variable line of

Illusion long.....248 mm.
Illusion short.....255 mm.

and later series yielded results of the same order. That is to say, the shadows, in both sets of experiments, were practically ignored. *H* explained in the vernacular that "we couldn't fool him with those shadows"; and the event proves him right.

These particular shadows, it will be remembered, lay upon the line of sewing thread, which was itself relatively narrow, and which had no vertical markers. If the shadows might be ignored, or abstracted from, under conditions thus favorable to their influence, it seemed to us that they might still more easily be ignored under the conditions of the earlier experiments, in which the horizontal line was relatively wide, and the three vertical markers stood out clearly upon the white background as the limits of the compared distances. To test this theory, we restored the apparatus to its original form, and made a series of experiments with one of our practised observers, Mr. Sailor. The instructions were that no attention should be paid to the shadows, but that judgment should be passed upon the lengths of the lines simply by reference to the position of the vertical markers. The results were as follows:

	Setting of Variable Line with Shadows Weak.	Shadows Strong.
Illusion long.....	250.5 mm.	251 mm.
" "	248	247
Illusion short.....	251	248
" "	252	249

The moral is clear. The observer is here able, by direction of attention, to resist the solicitation of a strong illusion motive, clearly presented. So much the more then will he, under the conditions of our first experiments, resist the solicitation of an illusion motive which he cannot see, of whose presence in the particular series he is entirely ignorant, and which is left out of account in the instructions given him by the experimenter.[1]

[1] *H*'s tendency spontaneously to ignore the illusion-motive from the outset is an interesting fact. One of the writers (*T*) has come across other

Summary and Criticism.

We have now shown:

1. That imperceptible shadows, raised almost to the limit of perceptibility, exert no influence upon the judgments of distance passed by five observers;

2. That shadows, so weak as barely to hold their form distinct, exert an influence upon judgment comparable with the influence exerted by strong and clear shadows;

3. That it is possible, by voluntary direction of attention, to free the judgment from the influence of a clear and strong illusion-motive.

In other words, we can find no experimental confirmation of Dunlap's results, and we believe that a more exact analysis of the conditions of his experiment shows these results to be illusory. We suggest, further, that imperceptible shadows, if they affect judg-

instances of it; but it does not appear to be common. Judd remarks (*op. cit.*, 38) that "early in the practice series both observers noted the feeling of having succeeded in abstracting from the oblique lines. That they had not done so appears in the fact that the illusion continued in almost its full original strength." There are, evidently, individual exceptions to the general mode of apprehension of the regular Müller-Lyer figure by unpractised or little practised observers.

We could not, then, generalise from *S*'s results, if the figure employed had been the regular Müller-Lyer figure. But, as is stated in the text, the figure employed was in so far different that the three vertical markers on the front of the screen afforded definite resting-places for the eye. The shadows were not, so to say, integral parts of the total figure shown; that figure was, first of all, a black line, with a long thin vertical at its centre, and short thick verticals at its two ends: the shadows were secondary. Under these conditions, abstraction from the shadows, with definite instructions from the experimenter to that effect, offers no special difficulty: *S*'s results were, as a matter of fact, confirmed by unsystematic experiments made with two other practised observers.

H evidently represents a case of self-suggested *A-Reaktion* (in Benussi's terminology), that is, of the reaction in which "die Versuchsperson . . . die Hauptlinie der Figur als einen selbständig und isoliert vorliegenden Gegenstand erfassen muss" (*op. cit.*, 310). He would not be 'fooled' by the shadows; he directed his attention to the horizontal line. His and *S*'s results agree with those of Benussi's prescribed *A*-reactions: "in der Tat hat Judd ungefähr 1500 Einstellungen gebraucht, um die Täuschung auf einen Wert zu bringen, der sich bei vorgeschriebener A-Reaktion nach *einigen* Einstellungen erreichen lässt" (*op. cit.*, 332).

ment at all, must affect it by more than the 0.5 mm. in 25 cm. which is the average of Dunlap's observations.

It remains, now, to seek an explanation of Dunlap's positive results. We said above that the method pursued in these experiments is not the method best suited to the problem. Similar exception may be taken to the apparatus. For while the setting of the distances is sufficiently accurate, the illumination is not under measurable control. We have spoken of "barely perceptible" shadows, but we have not been able to specify the amount of light thrown upon the back of the apparatus in any given series. We do not think that this lack of quantitative control at all invalidates our results; but we confess that, from the physical point of view, the experiment would have been prettier had such control been exercised.

Dunlap's work, after his preliminary experiments, was done with an apparatus in which the shadows were thrown upon the white screen from in front, and the amount of light employed to produce them was measured by means of an episcotister.[1] We did not reproduce this apparatus, partly because our results seemed conclusive, partly also because the apparatus is cumbrous, and appears likely to introduce new sources of error. We have still, however, to account for the positive outcome of Dunlap's investigation.

We grant, at once, that we can give no single or convincing explanation of these figures. All that we can do is to suggest the various possibilities of explanation that have occurred to us. Thus, (1) the average illusion-effect is, as we have pointed out, 0.5 mm. upon a standard line of 25 cm. Dunlap nowhere gives his *MV*; but there are indications in the paper that it must have been, at the least, as large as our own.[2] An illusion-effect of such inconsiderable amount, absolute and relative, might very well be ascribed to chance. (2) It is conceivable that the figures rest upon a miscalculation; experimental psychologists, from Fechner down, have been liable to slips in addition and subtraction. Nor is this suggestion as gratuitous as it may at first sight appear; for the paper

[1] *Op. cit.*, p. 440.
[2] *Op. cit.*, 445 f., 447 f.

shows at least two instances of careless handling. If the two plates on pp. 449, 451 are compared with the description on pp. 452 f., it will be seen that the lower diagrams of each plate have been interchanged: Figs. 7 and 8 should be Figs. 11 and 12, and conversely.[1] And again: if the table on p. 448 is scrutinised, two mistakes will be noticed. The difference between + 2.65 and + 1.75 is given as — .10; the difference between + 1.06 and + 0.78 is given as — .72. It is easy to read 2.65, 2.75, and 1.06, 1.78: but then the differences, instead of being *minus,* are *plus,*—that is to say, tell against Dunlap's conclusion. At all events, something is wrong, either with the principal figures or with their differences. (3) Dunlap's observers showed a progressive change of judgment throughout the experiment. Whatever may be the explanation of this change,[2] he tells us that three of his observers overestimated the right segment early in the experiment, and later underestimated it; while the fourth observer, "with a single exception, overestimated the right segment throughout the experiment, rather more

[1] Dunlap says that 5, 8, 9 are indifferent; 6, 10, 11 faintly in accord, and 7, 12 in striking agreement with his hypothesis. If we read 5, 12, 9; 6, 10, 7; and 11, 8, we bring the plates into accordance with the text. These changes, however, mean the replacing of the present 7, 8 by 11, 12, and conversely.

[2] The explanation must probably be sought in a general tendency of judgment, complicated by preferential direction of attention: it will be remembered that the experiments were doubly one-sided, in that (1) the standard line was always shown on the left, and (2) the variable was always increased from "shorter" to "equal," never reduced from "longer." The shift of judgment might have been checked by suitable instruction from the experimenter (Titchener, "Experimental Psychology," II., 1905, ii., 305 f.). How far practice was involved it seems impossible to say.—It is, of course, theoretically possible that the minute values obtained by Dunlap for the illusion-effect are due to a very high degree of practice with the Müller-Lyer figure. We have not seriously considered this possibility, (1) because Dunlap says nothing of preliminary practice; (2) because he gives no intimation that the illusion-values of his Table I. were different in kind from those of Table IV (see p. 450): (3) because he definitely ascribes the small values to the "circumstances" of the experiment, i. e., to the subliminal character of the shadows (p. 450): and (4) because, in view of Judd's and of our own results (our observer *G,* in particular, has had extended practice with this illusion-figure), we do not consider that Dunlap's experiments were numerous enough to reduce the illusion-average to 0.5 mm.

toward the last than the first."[1] For this reason, "in computing the averages, those for the shadowless series which were taken at the same time as the series with the illusion 'long' were kept separate from the averages for the shadowless series taken at the same time as the series in which the illusion was 'short.'"[2] It is clear, however, that shadowless and shadow-series could not, in strictness, be taken at the same time; they were taken successively. And, as the change of judgment was progressive, Dunlap's averages are used for the comparison of results that are, in strictness, incomparable. Under these circumstances, it is entirely possible that chance, in determining the order of the single series, may have played, so to say, into the hands of the illusion motive. (4) Dunlap does not tell us how he measured his lines: whether behind the screen, from angle to angle, or in front of the screen, from marker to marker. If he measured behind the screen, then the movement of the right-hand angle only every fifth time that the right-hand marker was moved[3] would introduce a constant error, which must, necessarily, operate in the same direction as an effective illusion motive. (5) Lastly, it may be observed, in general, that observers in method-work, however well-meaning, fall easily into a reliance upon secondary criteria; and that an apparatus of the kind used by Dunlap might easily admit this source of error. This suggestion must remain vague, since, without actual trial of the apparatus, we cannot say what the nature of the secondary criteria would be; the suggestion itself, however, does not seem to us unfair, whether in the light of our own experience or in that of Dunlap's account of his procedure.

To attempt, in this manner, to explain away the results obtained and the conclusions offered by another investigator is not a grateful task. Some of our suggestions may be put out of court at once by a word of explanation from Dunlap. The suggestion of a possible miscalculation —made by us, be it repeated, only on the ground of positive evidence of careless treatment—should be offset by the admission that Dunlap planned his experiments carefully, and with

[1] *Op. cit.*, 447 f.
[2] *Op. cit.*, 448.
[3] *Op. cit.*, 442.

due regard to the dangers of bias and partiality. But in any event, whether or not we have hit upon the right explanation of his results, there can be no doubt that these results are themselves untenable. Our own experiments point unequivocally to the one conclusion that, if the subconscious is to be received into experimental psychology at all, it must find some other means of access than these imperceptible shadows.

NOTE AS TO THE MEASUREMENT OF THE ACTION OF WATER UPON METALS.

By WILLIAM PITT MASON, M.D.

(*Read April 19, 1907.*)

Reports recording that a water contains so many parts per million of lead, zinc or other metal are common enough, but it is rare to find advance statements of what a water is capable of doing in the way of dissolving metals should opportunity be afforded it of coming in contact with them. In other words, a client who possesses a water supply which is very desirable at its source is seldom informed of the possible damage which may result thereto by reason of its being conveyed through metallic piping.

After the pipes have been laid and the water admitted to them, record is made of the result as to the metallic solvency, but little is found in the nature of a prophecy antedating the outlay of capital; which prophecy had it been uttered in time, might have had material bearing upon the investment. Again, if, as occurs in a few instances, the client be told that the water under examination is capable of acting upon certain metals, he is not given the information in such quantitative form as will enable him to make comparisons between it and other waters with reference to this property.

It is well known that all waters do not equally possess the power to attack metals and it is proper to ask that, granting such power to exist, how far is its exercise objectionable from a sanitary point of view; or, to state it differently, what amount of metallic salts in solution may be allowed with safety?

The interesting case is given of "A water from the tail-race of a gold and silver mill which showed the presence of 350 parts of lead, 51 parts of copper and 1666 parts of arsenic oxide per million of water. This water, which was supposed to have caused the death of a number of cattle, was so highly charged with arsenic

that an ordinary drink for man or beast would contain sufficient to kill."[1]

Such a special instance, however, does not come within the limits of the present inquiry.

Let us consider for a moment the question of "plumbism" or lead poisoning, as it is ordinarily presented under the classification of a water-borne disease.

The Massachusetts State Board of Health enumerates the symptoms of lead poisoning as some or all of the following: Anæmia, constipation, indigestion, loss of appetite, thirst, metallic taste, abdominal pain, colic, "drop wrist," blue line at margin of gums, lead in the urine.[2]

Dr. Hunter describing the effects of the epidemic at Pudsey, says: "Anæmia and debility were the most common symptoms. Patients nearly always complained that they felt as if they would sink down from weakness, and that the least exertion would make them sweat freely. The majority had the blue gum-line so characteristic of lead poisoning. Colic was a common symptom. Paralysis was not common, but there were five or six cases of almost general paralysis and in these cases drop-wrist was included. The amount of lead found in the waters producing these effects varied from .01 to 1 grain or more per imperial gallon (.143 to 14.3 per million)."[3]

There is some difference of opinion among the authorities as to the amount of contained lead required to condemn a water, but all are agreed that even small quantities should be narrowly watched. Thus, the Massachusetts reports note that one-half part per million has caused serious injury.[4] Haines holds that .1 grain per U. S. gallon (1.71 per million) should cause a water to be rejected.[5]

Whitelegge believes that "No water should be used for drinking which contains more than one part of lead per million, and any trace, however minute, indicates danger." (Hygiene and Public Health.)

[1] Utah Agr. Expt. Sta. Bull. 81, p. 199.
[2] Report of Mass. State Board of Health, 1898, XXXIII.
[3] Thresh, "Examination of Water," p. 88.
[4] Mass. State Board of Health, 1898, XXXII.
[5] *J. Fk. Inst.*, Nov., 1890.

To quote Dr. Summerville in his recent paper in *Water:* "Lead to the extent of .25 part per million is sufficient to condemn a potable water."

That sundry waters contain enough lead to prevent their acceptance by at least some of the standards above laid down is shown by the fact that a few years ago it was reported that sixty-three (63) cities of Massachusetts possessed public water supplies which contained lead in amounts varying from 85.46 to .023 per million. In four of these cities where lead poisoning was pronounced the average amount of the metal present during ordinary daytime use was one part or over per million. Occasional instances of "plumbism" were noticed in other towns and doubtless mild or unrecognized cases occurred elsewhere.[1]

In the 31st annual report of the London local Government Board (1901 and 1902 Supplement on Lead Poisoning and Water Supply, Vol. 2, page 426), peaty moorland waters are shown to be especially plumbo-solvent, to a degree chiefly governed by the amount of acidity present, and experiments show that such acidity is due, at least in part, to acid-forming bacteria residing in the peat.

For instance, the influence of acidity is shown by the action of the following moorland waters from Lancashire and Yorkshire:[2]

Acidity of water in terms of c.c. of N/10 Na_2Co_3 required to neutralize 100 c.c. of the water.	Milligrams of Pb. in 100 c.c. of the water after filtering through lead shot.
0.2	.28
.3	.25
.4	.4
.5	.66
.6	.92
.8	1.5
.9	2.4
1.1	3.2
2.2	8.6

The London report already quoted is so firm in its belief that the cause of plumbo-solvency has been located that it ventures to rate moorland waters as "safe" if they are neutral to lacmoid and as "dangerous" if they react acid with that indicator. Attention

[1] Mass. State Board of Health, 1898, p. 543.

[2] Thresh, "Examination of Water," p. 186.

is also called therein to the fact that moorland streams are highest in acidity during wet weather because of drainage from peaty surface sources and less so during periods of no rain on account of their supply at such seasons coming from the flow of springs.

In this connection it may be noted that H. W. Clark observed that carbonic acid in a soft water was the main factor that caused lead to be taken into solution by the waters of Massachusetts.[1]

It is by no means new to distinguish between the "solution" of lead and that "erosion" of the metal which some waters exercise whereby insoluble lead salts are formed with appreciable increase in the turbidity of the water.

Such classification of the action upon lead has been developed by the report of the London Local Government Board with great care.

For our purposes it will suffice to note that "erosion" does not occur in the absence of oxygen, and we are also to remember that from the sanitarian's point of view "erosion" may be fully as objectionable as "solution" if no opportunity for clarification be furnished. In fact, the former may readily be the greater evil of the two, because of its involving the possibility of the ingestion of large quantities of lead salts held in suspension.

Piping water in tubes of galvanized iron is very common, and as zinc is often more easily attacked than lead it is pertinent to ask if it be equally dangerous. So far as our present experience can guide us towards a correct solution of this question, the reply must be a negative one and the following opinions are presented in support of such contention:

In the journal of the German Society of Gas and Water Engineers for 1887 H. Bante collected statistics to show "that the use of galvanized pipes should be in no way detrimental to health."

Similar views are entertained by V. Ehmann, director of the water supply of Wurtemberg.[2]

According to Thresh[3] "There is no doubt that waters containing traces of zinc are used continuously for long periods without

[1] *Engineering News*, Dec. 1, 1904.
[2] *J. Fk. Inst.*, Nov., 1890.
[3] Examination of Waters and Water Supplies, p. 85.

causing any obvious ill effects. The water supply to a small hospital with which I was connected for some years always contained a trace of zinc, probably never more than half a grain of the carbonate per imperial gallon (7.1 parts per million), but I never observed any indications of its being deleterious, although such effects were looked for."

In the Massachusetts Board of Health report for 1900, page 495, the following table is given showing amounts of zinc in sundry public supplies, the metal having been dissolved from pipes of galvanized iron or brass during ordinary use. The results are averages and are in part per million.

West Berlin	18.46
Milbury	3.08
Newton	1.25
Marblehead	0.85
Grafton	0.73
Wellesley	0.68
Fairhaven	0.52
Lowell	0.33
Webster	0.28
Sheffield	8.65
Palmer	2.90
Beverly	2.71
Fall River	0.07

The first of the above, West Berlin, drew its water through four thousand feet of galvanized iron pipes. The quantity of metal dissolved therefrom was certainly large but appears to have produced no evil results. "As far as is known the amount of zinc present in these waters as used is not sufficient to have any effect upon the health of the consumers of the water."

"The Board has investigated the question of the presence of zinc in drinking water supplies where galvanized iron pipes are used and, except in case of the use of some ground waters, containing very large amounts of free carbonic acid, which dissolves zinc and many other metals very freely, the amount of zinc found in ordinary water supplies, where galvanized pipes are used, is not sufficient, in the opinion of the Board to give anxiety."[1]

[1] Massachusetts Board of Health, 1902, XLIII.

In a private letter of more recent date the president of the above mentioned board says: "If there had been any harmful effects of the presence of zinc in the public drinking waters of the state that fact would have undoubtedly been brought to our attention. No statement to this effect has been made, nor has there seemed to this board reason suspecting serious danger from this source."

As an instance of long continued use of a water containing much zinc, the case of Brisbane, Queensland, should be quoted. In that city rainwater tanks built of galvanized iron are found in all the houses. The water, which is in common use, contains about 17.1 parts per million of zinc, yet no harmful effects have been observed.[1]

In his experience the writer has been unable to trace any evil effect due to the presence of zinc in drinking water, even when the quantity rose as high as 23 parts per million in a water which is in constant use. It might be well to add, that in the particular case just cited the zinc was derived from a long stretch of galvanized iron pipes and the amount of the metal present was subject to great and frequent fluctuations for reasons that were not apparent.

It must be admitted however, that, even on the assumption that the presence of zinc in a water is of no sanitary significance, its being there is nevertheless not desirable, and the probability of a supply being able to dissolve it should be determined and reported.

What can now be said with reference to some convenient and standard method of reporting the possible action of water upon any of the common metals?

The suggestion offered is this:—Let the action, whether solution or erosion, be stated in parts per million, and let it be that of one litre of water acting upon one square decimeter of bright metal for one hour at 15° Centigrade.

The mode of procedure followed by the writer is to submerge a piece of bright sheet metal, one decimeter square in two liters of water contained in a wide-mouthed bottle. The water is oc-

[1] Hazen, *Eng. News*, April 4, 1907.

casionally given a gentle motion and is kept at 15 degrees for one hour, after which time the metal in solution or suspension is determined. One hour is sufficient time to allow of the watching of metallic solvency, and let it be added, the limiting of the time of action to the standard period is important, for the rate of action of the same water is not only variable but the ratio of the total action during different lengths of time is not a simple one. Thus, the quantity of metal attacked in ten hours is by no means ten times that acted upon during one hour.

In conclusion, let it be said that although we know in a general way that softness, acidity, dissolved gases and the presence of much chloride or nitrate will tend towards metallic action, while alkalinity and hardness are rated as protective agents, yet it is far better to actually test a water with reference to its behavior towards metals than to attempt any prophecy of its action based upon analytical knowledge of what the water may contain.

TROY, N. Y.

PRODUCTION OF SYNTHETIC ALCOHOL.

By H. W. WILEY and HERMAN SCHREIBER.

(Published by permission of the Acting Secretary of Agriculture.)

(*Read April 20, 1907.*)

When Faraday and Hennell[1] discovered that ethylene would combine with sulfuric acid, forming ethyl sulphate, a new opportunity was given for the quest of new compounds derived therefrom. The whole subsequent history of synthetic alcohol is a mass of methods and contradictions of them. Fritzsche[2] claims that Hennell[3] first demonstrated the identity of the alcohol, made by diluting ethyl sulfate with water and distilling off the alcohol, which is plain from the above reference, while others claim that Berthelot first made this observation. Berthelot[4] did produce alcohol from ethyl sulfate and being engaged in investigating coal gas which was known to contain ethylene he proposed that alcohol could be made from the ethylene in coal gas, but his efforts in this direction did not make its utilization appear of commercial value. However, the alcohol fever had gained a strong hold on the people, which finally lead to the offering of stock in a concern whose object was the manufacture of ethyl alcohol from coal.[5] Cotelle, the promoter of this scheme, claimed to produce one hectoliter for 23 francs.[6] Fritzsche[7] states that it is doubtful that any commercial attempt was made. The chief difficulty in producing alcohol from the ethylene in coal gas at this time seemed to be the cost of reconcentrating the sulfuric acid resulting from the diluting and distilling of the ethyl sulfate. But Fritzsche claims that the enormous dilution then practiced (5–6 parts water to 1 ethyl sulfate) is not necessary and that

[1] Gmelin Krauts, "Handbook," Vol. 4, p. 721.
[2] *Chem. Ind.*, 1897, Vol. 20, p. 266.
[3] *Philosophical Trans.* 1828 p. 365.
[4] *Comptes rend.*, Vol. 40, p. 102.
[5] Wagner's "Jahresbericht," 1863, p. 469.
[6] *Chem. Ind.*, 1897, 266.
[7] *Chem. Ind.*, 1897, 266.

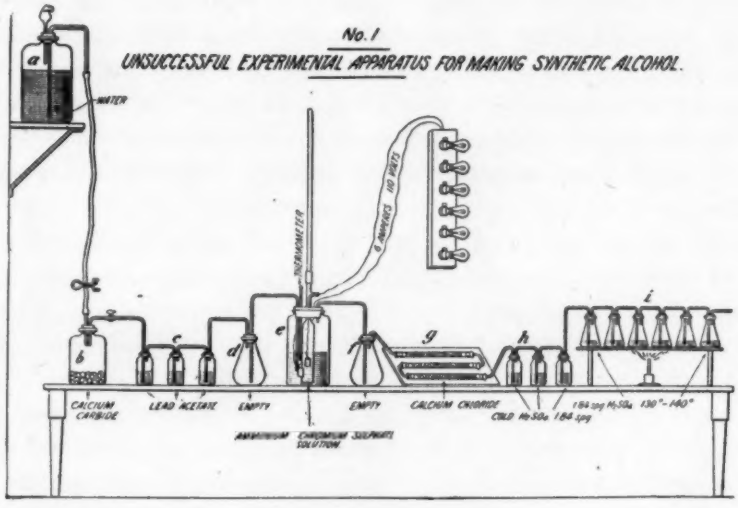
dilution with an equal weight of water will give nearly the entire ethyl content as alcohol. He estimates that 95,000 hectoliters alcohol could be produced from the coal gas which is annually produced in Germany. As we do not know that alcohol is at present produced from coal gas we suppose that there are still difficulties which prevent it.

The matter has not yet lost all its interest and appears occasionally even in economic guise. Since the commercial production of calcium carbide much interest has centered in the possibility of building alcohol from it. Frazee[1] gives four possible methods of building alcohol from acetylene. The first consists in passing hydrogen and acetylene over platinum black and so gaining ethylene according to the equation $C_2H_2 + 2H = C_2H_4$ then absorbing the ethylene in sulfuric acid, diluting the ethyl sulfate and distilling off alcohol, $C_2H_4 + H_2SO_4 = C_2H_5HSO_4$: $C_2H_5HSO_4 + H_2O = C_2H_5OH + H_2SO_4$. This method was not tried as Wilde[2] states that if hydrogen and acetylene are passed over platinum black ethane is formed and no ethylene. Frazee's second possibility is to build ethane from acetylene then make the chlorine substitution product (ethyl chlorid) and saponify this with KOH. This method would undoubtedly give alcohol but in a round about way. His third method is the building of acetaldehyde from acetylene and reduction to alcohol. This method is the best of the four which he gives and was the one by which we were finally able to make alcohol. His fourth method is the ethylene iodide method which consists in absorbing acetylene in hydriodic acid, oxidizing the ethylene iodide to acetaldehyde by means of lead oxid and then reducing the acetaldehyde to alcohol. This method has been found very difficult by Krüger and Pückert[3] and was not tried by us.

Of all the methods found by us, the one given in *The Electrical Review* (for 1899, page 375) seemed the simplest and most direct. Here the acetylene is absorbed by a solution of chromium ammonium sulfate in which hydrogen is generated electrolytically which converts the acetylene to ethylene. This ethylene passing out of the

[1] *Iowa Academy of Science*, 1904, Vol. XII., p. 179.
[2] *Berichte*, 7, 1874, p. 353.
[3] *Chem. Ind.*, 18, 1895, p. 454.

solution is absorbed by strong sulfuric acid and forms ethyl sulfate from which alcohol is made by dilution and distillation. Apparatus No. 1 was constructed to carry out this scheme. The acteylene was generated in a two-quart Mason fruit jar (*b*). Water was fed into this jar by means of a bottle (*a*) elevated so that water siphoned from it would have a fall of six feet. The exit of the acetylene was regulated by a glass valve. The gas then passed through 3 bottles (*c*) containing lead acetate to take out sulfides, then through an empty flask (*d*) which was to take care of back pressure and then into the electrolytic cell (*e*) to be absorbed and regenerated as



ethylene, from here it passed an empty flask (*f*) to catch water which the gas might carry mechanically, then through three sixteen inch glass tubes (*g*) filled with calcium chloride, then three bottles (*h*) containing strong sulfuric acid (cold) to dry as thoroughly as possible and then into six flasks (*i*) containing strong sulfuric acid which was heated to 130° to 140° C. by means of a bunsen burner under the sand bath on which they stood. The current was modified by passing 6 32-c. p. lamps so that it was cut down to 6 amperes at 110 volts. This gave approximately 3 liters of hydrogen per hour and the flow of acetylene was so regulated that the quantity passing should be about 2½ liters per hour, or about 10 times

the weight of the passing hydrogen. The chromium ammonium sulfate was made acid by 10 cc. of concentrated sulfuric acid to prevent deposition on the electrodes and was kept at a temperature approximately 40° C. as directed in the method. If the six bottles (containing strong sulfuric acid) intended to absorb the ethylene were kept cold they remained colorless but if heated they became brown, then black, and finally were thick in consistency. On diluting with water and distilling this material foamed and bumped violently so that it was impossible to distil it even on great dilution if the absorption had been carried on for several days. The process was therefore run only a few days from 1–3. The sulfuric acid was then diluted and distilled. The distillate smelled strongly of sulfurous acid and somewhat of aldehyde and gave the iodoform reaction but no alcohol could be isolated by fractionation. The contents of the three bottles containing cold sulfuric acid (which was brown also) was diluted and distilled. The distillate smelled strongly of aldehyde, gave the iodoform test and formed resins with alkali but alcohol could not be fractionated from it. The process was varied by removing the calcium chloride tubes and also by not heating the sulfuric acid, but alcohol was not obtained.

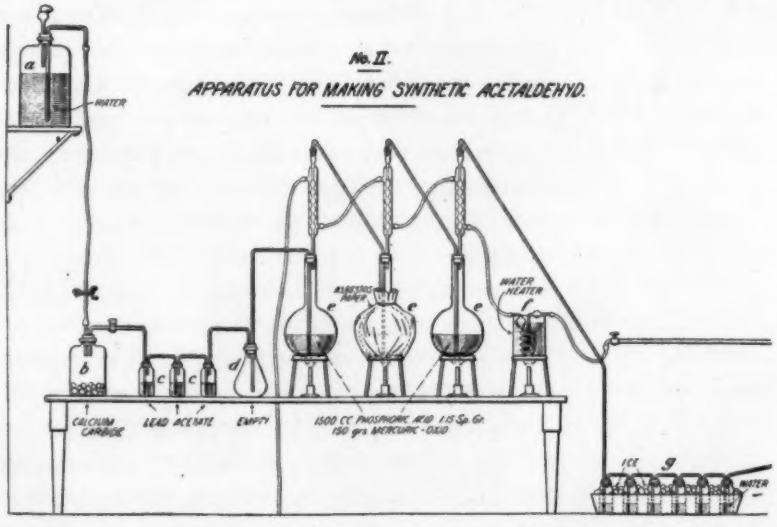
Beilstein[1] states that ethylene is produced when ammonia reacts on a mixture of zinc dust and copper acetylide. Wood[2] says that he was unable to make any alcohol when he used this method for producing ethylene. Due to the excitable temper of copper acetylide this method was put off to be tried only as a last resort and as we reached the desired end by another method, was not tried at all.

The aldehyde method was another possible way of procedure. But here again the literature is decidedly contradictory. Lagermark and Eltekow[3] state that acetylene treated with sulfuric acid sp. gr. 1.35 (45–46%) and then distilled gives crotonaldehyde. Erdmann and Kothner[4] state that acetylene passed into a hot solution containing one volume water and two volumes sulfuric acid is converted to crotonaldehyde and that acetylene passed through a mixture of

[1] "Handbuch," 3d ed., p. 128, Vol. 1.
[2] *Chem. News*, (78), 1898, p. 308.
[3] *Berichte*, 10, 637.
[4] *Zeit. Anorg. Chem.*, 18, 1898, p. 55.

three volumes of sulfuric acid and seven volumes water is converted to acetaldehyde or that approximately 75 per cent. sulfuric acid gives crotonaldehyde, and 42 per cent, sulfuric acid gives acetaldehyde. These figures assume that Erdmann and Kothner mean H_2SO_4 1.84 sp. gr. when they say "concentrated." The latter also find that addition of mercuric oxid facilitates the process and that phosphoric acid of sp. gr. 1. 15 may be used, which they claim gives a purer acetaldehyde than sulfuric acid.

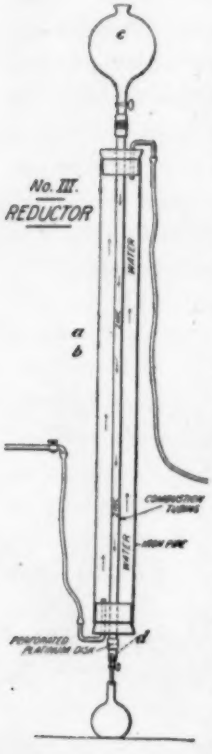
Apparatus No. 2 was constructed to carry out Erdmann and Kothner's method. The acetylene was again generated in a fruit jar (*b*) and washed through lead acetate[1] (*c*) then through an empty flask (*d*) to catch any liquid forced back by back pressure. From here it passed through 3 round bottom Jena flasks (*e*) (3 liter) containing 1500 c.c. sulfuric acid (3 volumes acid, 7 volumes water) and 100 grams mercuric oxid. To prevent bumping, glass beads were put in the flasks and the flasks wound with asbestos paper. The



flasks rested on shallow sand baths heated by a bunsen burner. Each flask was closed by a rubber stopper carrying a reflux condenser for exit and a $\frac{3}{16}$-inch glass tube reaching to the bottom of the flask for entry of gas. The reflux condensers were fed by warm water

[1] "Lehrbuch der anor. Chem.," Erdmann, 4th ed., p. 437.

from (*f*) to prevent the condensation of aldehyde as much as possible. However, the solutions soon became dark and the mercury was reduced to the metallic state where strong acid was used. The gas was run through three conversion flasks with the idea that the yield of aldehyde would be greater. The gas was now treated in various ways, sometimes washed through cold water (*g*) and sometimes through ammonia or sodium bisulfite. The latter ways were abandoned as the aldehyde in a solution of ammonia or bisulfite is resinified on standing. Attempts to reduce the aqueous aldehyde by means of sodium amalgam were unsuccessful as our method of manipulation was faulty, and not according to the one devised by Wurtz.[1]



The reduction of pure acetaldehyde (Kahlbaum) by passing it over palladium (precipitated on asbestos) together with hydrogen was tried but without success. Various temperatures from 20° to 400° C. were used in these experiments. Acetic acid[2] and zinc were not tried as the evolution of hydrogen is slow and acetaldehyde is very volatile. Acetaldehyde was diluted and attempts made to reduce it by sulfuric acid and zinc but without success as the evolution of hydrogen is slow and the process was not carried on long enough. Apparatus No. 3, a Jones reductor, was now erected consisting of a piece of combustion tubing (*b*) five feet long encased in a large gas pipe (*a*) by means of rubber stoppers and cold water circulated between the two. A separatory funnel (*c*) was attached to the top of the combustion tubing by means of a rubber tube and a small perforated platinum disk formed the bottom of the tube which was extended beyond the disk by a three inch piece of the same glass tubing (*d*) to allow the insertion of a rubber stopper carrying a glass stopcock so that the reductor could be regulated

[1] Wurtz, *Liebigs-Annalen*, 123, p. 140.
[2] *Berichte*, 16, 1717 Krafft.

if necessary. The inner tube contained commercial zinc (mossy). About 25 cc. pure aldehyde were mixed with one liter dilute hydrochloric acid (four volumes acid 1.20 sp. gr. to six volumes water) and passed through the reductor until the evolution of hydrogen was very small. The zinc was then precipitated out of the resulting liquid by sodium carbonate to prevent bumping during distillation. The zinc being filtered off the filtrate was distilled. The distillate was made alkaline with caustic potash and silver nitrate added to oxidize aldehyde and after standing over night the silver was filtered off and the filtrate fractionated. The last distillation was made from an oil bath, a side necked test-tube being used as a retort. The liquid was allowed to stand over anhydrous copper sulfate before this distillation. In this way a fraction was obtained which boiled at 78°–78.7° C. and had the odor and taste of ethyl alcohol.

Trials were also made with the reductor using zinc amalgam and sulfuric acid, and zinc amalgam and hydrochloric acid, and then using zinc and sulfuric acid, and at last zinc and hydrochloric acid which proved best. The reductor was adopted in preference to making the reduction in a bottle as the liquid in passing over the zinc was thought to give more intimate contact between the acid, aldehyde and zinc than could be obtained by means of a bottle. Aldehyde was now made by the Erdmann-Kothner method by means of apparatus No. 2. The converters were charged with 1500 cc. phosphoric acid sp. gr. 1.15 and 150 grams mercuric oxid. The aqueous aldehyde obtained by running the apparatus 14 hours was mixed with 2 liters dilute hydrochloric acid (4 volumes acid to 6 volumes water) and the mixture passed through the reductor (apparatus No. 3) after reducing the zinc was precipitated and filtered out, the filtrate distilled and the aldehyde oxidized by silver nitrate, the filtrate from the precipitated silver was fractionated and a small fraction was obtained whose boiling point was 77.5°–78.9° C. and which had the characteristic taste and odor of alcohol.

THE PROGRESS OF THE ISTHMIAN CANAL.

By ELIHU THOMSON.

(*Read April 19, 1907.*)

It was the privilege of the writer to be one of a party which visited the Canal Zone, as it is termed, on March 1 and 2 last. The expedition was organized for an inspection of the conditions and progress of the work there going on. In view of the conflicting accounts which from time to time had been published, plans for a visit and personal inspection of the actual conditions were matured last fall.

The party was composed of about ninety men, members of the Commercial Clubs of Boston, Chicago, Cincinnati and St. Louis, many of whom are at the head of large enterprises of varied character in the cities mentioned; often closely connected with public activities. There were presidents and other officers of railway, express, power and other public service corporations, managers of mills and varied manufacturers, heads of commercial enterprises, banking institutions, fire insurance, and a few professional men such as lawyers and engineers. The mayor of the city of St. Louis and ex-Governor Francis, the president of the Louisiana Purchase Exposition were of the party.

A steamer of the Hamburg-American Line, specially fitted up for travel in the tropics, and chartered for the trip, sailed from New York on February 18 with about twenty passengers, mainly the Boston contingent, and reached Charleston, S. C., two days later, where the members from the western cities embarked. After a direct run to the island of St. Thomas, of the Danish West Indies, and a brief visit to Porto Rico, the ship left the southern port of the island, Ponce, for Colon. During the run about nine hundred miles southwesterly from Porto Rico, much time was given to securing an effective organization of the passengers, so as to obtain as much information as possible in a short time. To this end there were formed eight committees each composed of from ten to twelve

men. Specific subjects were selected, one for each committee, subjects which related to the sanitation, plan of administration, food and commissary work, housing, social and labor conditions, effects of climate on Americans, efficiency of plant and progress of work. Those serving on any particular committee were chosen in accordance with their special aptitude or training in the subjects with which it was to deal. The chairmanship of one of these divisions was entrusted to the present writer. Before the arrival at Colon, the organization was in good working shape, and in some instances, to assist the work, a further division into sub-committees was made.

Wireless communication with Colon permitted requests to be forwarded to the effect that upon the arrival there, the canal officials in charge of the particular phases of the work might meet the respective committees prepared to furnish such information as might be sought by them. To render this effective, the committee had, beforehand, formulated a scheme of inquiry to be followed if possible, upon arrival at the Canal Zone.

In the special message of the President to Congress on December 17, 1906, concerning the Panama Canal, which followed upon his personal visit to the isthmus, he referred to the expected visit of the commercial clubs, and promised that every facility would be given them "to see all that is to be seen in the work which the government is doing." He says further: "Such interest as a visit like this would indicate, will have a good effect upon the men who are doing the work, on one hand, while, on the other, it will offer as witnesses of the exact conditions men whose experience as business men, and whose impartiality, will make the result of their observations of value to the country as a whole."

The journey from Porto Rico to Colon was through the comparatively calm and warm tropical sea, swarming with flying fish, which rose in flocks as the steamer moved among them. The weather conditions were good, and the temperature of the air, both night and day, owing to the prevalent trade winds, was not warm enough to cause any discomfort. A special train on the Panama Railroad had been arranged for to meet the body on its arrival at Colon, which took place on the morning of March 1. Each car

of this train on the journey across the isthmus, was occupied by two of the committees, eight in all, and with them were the officials of the Canal Zone having special charge of the subjects upon which the particular committee was to seek information. It is fair to say that this was in all cases given freely and courteously with the utmost frankness, calculated to elicit the fullest interest and sympathy.

After leaving Colon on the trip southeasterly to Panama, a number of stops were made at various points along the route of the canal. At Christobal near Colon an inspection of docks, machine shops and other shops for repair and construction, was made. Here the equipment was found to be modern and well adapted to the work, and there seemed to be a good force of skilled machinists and other workmen, among whom were many Swedes. Similar large shops exist at other points, notably at Empire not far from Culebra.

The working forces seemed to be in excellent physical condition. From Christobal there runs for several miles the canal dredged by the French. Owing to change of location this does not become part of the accepted plans, and will be used only for transporting materials and machinery to the vicinity of Gatun, about seven miles from Colon, the site of the proposed great dam known as the Gatun dam. Leaving the train at this point the hill at the east end of the proposed dam was climbed and the site of the great canal locks to be constructed here was reached. The weather conditions were so good that even in the tropical sun no discomfort was experienced even in briskly walking up hill. This was due to the cool trade wind coming from the east.

From the Gatun Hills, looking across to the farther hills where the other end of the dam will rest, one begins to acquire an impressive sense of the magnitude of the whole enterprise, such as no amount of reading or examination of maps or plans can give. Here several large steam shovels, and construction trains were actively in service, excavating at the lock sites and building part of the embankment of the dam itself.

There has been much discussion of the subject of a canal with locks as against a true sea-level waterway, the latter project being

favored by many of the foreign engineers, while the decision of Congress to build a lock canal was made, as is well known, in accordance with the recommendation of the American engineers. The writer does not profess to be able to judge between these two schemes. It would be presumption for one who, though much of his work has been engineering of a special kind, is not experienced in civil engineering, much less in such matters as have divided the opinions of many of the foremost engineers of the time, who have been called upon to devote a long period to their consideration. All that is attempted to be recorded here is an impression; which may not be worth much. Still it is an impression. The writer had previously in common with many others, conceived the idea that it would be a mistake to build any other than a sea-level canal, but upon arriving at the site of the Gatun dam, and witnessing the conditions, this idea soon gave place to a feeling that the lock canal project was probably a correct solution. Nothing has since been learned tending to change this impression, which, in fact, was more and more confirmed or strengthened as the further inspection of the work in the zone was pursued.

The problem of the Chagres River floods which was so serious in the case of a sea-level canal solves itself in the lock canal, with the dam at Gatun. This structure when completed will impound the river water even in heavy floods and form above the dam a great fresh-water lake of about one hundred and ten square miles in area, the level of which will be about 85 feet above the sea. For about twenty miles ships will be able to steam at good speed in this elevated lake and make up for time lost in passing the locks, so that the actual time of passage through the canal may not differ greatly from that which would have been needed in the case of a sea-level construction. On the right of the proposed dam, as one faces Colon, was seen the site of the three great locks, which will be built in flight and in duplicate. In fact, the work of excavating for them had been begun, as before stated. The locks being in duplicate will permit simultaneous passage of ships both ways, or up and down. They will be of size enough to accommodate, with considerable margin, the largest vessels in existence; greatest length, breadth of beam and draught.

The dam itself is to be in reality a great earth bank spanning a distance of about 7,700 feet between the hills, and it will be not less than 2,600 feet wide at its base, tapering to a crest of about 100 feet wide and this crest will be considerably over 100 feet above sea level, with a great concrete spillway near its center. At the site of the dam, careful rock soundings have been made, a work which was still going on, and samples brought up from various depths were examined. These show that at distances from the present surface of the ground, varying from a few inches to 200 feet or more, a solid compact rock, called indurated clay, sometimes including fossil marine shells, exist; slaty gray in color. The engineers seem so far to be satisfied with the nature of the foundation on which the great dam will rest, in view of its great width at the base, which is regarded as giving ample stability.

The material required for the construction of the dam will be largely that brought down from the heavy cutting at Obispo and Culebra, though at the time of the visit of the writer, none of this was being used at the dam, as the transportation facilities had not been completely arranged. The problem is one of transportation and the conditions will be much improved when the double tracking of the Panama Railroad is completed. This with the exception of nine miles, had already been done. Besides this, many large modern locomotives and construction cars are soon to be added to the plant, already so extensive. In the meantime, some of the small capacity dumping cars left by the French Company are being used, as are also some of the numerous small French locomotives, found along the line. The parts of some twenty-five or thirty new locomotives were seen on flat cars, awaiting assembly at the shops in the zone.

Leaving Gatun, the railroad follows up the Chagres River at a varying distance therefrom, through a country which is at first but slightly hilly, but which becomes more and more rolling. It is for the most part covered with a thick growth of tropical jungle, with some cleared spaces. Here and there along the route are small groups of huts or shacks inhabited by negroes; remains of a mode of life which will gradually be eliminated from the zone. Often the views from the train are most picturesque, as river vistas and

stretches of country come into view bordered or covered by the bold and intensely colored foliage of tropical plants. At last the river valley leads off to the east and the train moves toward the beginnings of the deep cutting at the divide.

At Bas Obispo over thirty miles from Colon is the great rock cut and since the general course of the canal is southeast, this cut is about five miles to the northwest of the celebrated Culebra cut, where the greater part of the excavating work needed is now done and has still to be done in the future. From the Gatun dam there will be about thirteen miles of flooded river valley deep enough for ships of the greatest draught without dredging or excavation, but for the rest of the distance toward Bas Obispo material in increasing depth will need to be removed.

The French left the level of the cut at Bas Obispo at about 100 feet elevation, which has since been cut down by the Americans to 74 feet up to March 1. To satisfy the condition of an 85-foot water level some thirty-four feet more in depth will be removed. The deepest cutting done and yet to be done, is at the true divide or Culebra cut. At Bas Obispo, but more especially at Culebra, are the evidences of the great amount of work which had already been done by the French. In fact, the real work of building the canal is here. To complete this section of the canal, a length of about nine and one half miles, will require the removal of about 50,000,000 of cubic yards of rock and earth in addition to that which has been taken out hitherto. At the station called Empire, between Bas Obispo and Culebra, a stop was made for viewing the shops located there, and to allow a glimpse of some of the discarded French machinery to be had. Here rows of beautifully built, but according to present standards, small-sized locomotives of French make are found partly overgrown with vines. The workmanship of these and other remains of French plant, so bountifully strewing the canal route, is highly esteemed by the present engineers. The fault of small size or capacity, it is only just to say, would have characterized such machinery in general at a time twenty or more years beck. A considerable number of these French engines are actually in service now. Their refined construction is sufficiently indicated by the fact that they have copper fire boxes and white metal fire tubes.

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On the way from Bas Obispo to Culebra the evidences of great activity were numerous. Stone cruchers, roundhouses, coal chutes, air compressing plants for drills and the present dumping grounds were seen in succession. Camp Elliott, with a body of U. S. marines, the auditing and disbursing officers of the Isthmian Canal Commission, the Circuit Court District No. 2, the officers of the engineer of the Culebra Division, etc., were passed.

Near the great Culebra cut was found the apparently flourishing town of Culebra. Here are situated the administration offices and the headquarters of the chief engineer, Mr. John F. Stevens, who here joined the visiting party. The great Culebra cut was seen; not very different in aspect from the time when the task was given up by the French company. Here as at Bas Obispo, work was in active progress, huge steam shovels being used, some of which were capable of lifting at one time as much as five cubic yards of broken rock or earth, after it had been loosened by explosives, and depositing it upon the construction cars in long trains, in which it was hauled away and dumped. The tracks on the dumping grounds, as well as in the area of excavation, are required to be quickly moved or relocated; a necessity which has led to the devising, by one of the engineers, of a plan for quickly shifting portions of the line sideways to a distance of nine feet without disjointing it or loosening it from the ties. The town of Culebra, like the other settlements in the zone, is remarkably clean. Much care has been given to the proper placing and construction of the buildings. Here in a large hotel restaurant the visiting party partook of a midday meal which was well prepared and served. There was no annoyance from flies, mosquitoes, or other insect pests. In fact, the writer believes it to have been the general experience that no mosquitoes were encountered anywhere in the Canal Zone. It may possibly have been the season when they are naturally scarce or absent, or the absence may have been due to preventive measures. While traversing the Culebra cut in flat cars provided with improvised seats or benches, men belonging to the mosquito brigade were noticed sprinkling oil on small pools or sluggish streams within the cut. The sanitation of the zone will, however, be alluded to further on.

Within the Culebra cut the highest point of the divide is now about 167 feet above sea level, having been originally or before any cut was made about 333 feet. The French cut down 160 feet. At this point the additional cutting required to complete the canal is about 127 feet. A total depth of cut of about 290 feet will thus be needed. A sea level canal would have made this 375 feet. Naturally the amount of earth to be removed increases with the depth because the greater depth requires much wider cutting to provide reasonable slopes safe from landslips, and the length of the excavation is likewise greatly extended. The money expenditure for the sea level project as well as the time needed would have been several fold more than for the lock or present plan.

Explosives are used both in the rock at Obispo and in the compact earth at Culebra and in January last, it is reported, about eleven miles in total length of holes were drilled for blasting. Beyond Culebra the site of the first lock on the Pacific side, which is known as the Pedro Miguel lock, was soon reached. It is to be a duplicate lock with a single drop from the 85-foot level, of about thirty feet or a little less.

At its foot another fresh-water lake at 55 feet above sea-level will be made by dams at a place called La Boca, about two miles from the city of Panama and to the west thereof. The area of this lake will be upwards of ten square miles. Alongside of the La Boca dam will be located the Sosa locks at Sosa hill. These will be in duplicate and in a flight of two with level differences of about 27 feet or more, or 55 feet for the two locks. Inasmuch, however, as the maximum tides at Panama are as great as 24 feet, provision for variation in the lock levels is made in accordance therewith. At Colon the tides are a little more than 2 feet. From the foot of these locks at Sosa a channel is to be dredged straight out to sea in the Bay of Panama, the locks at Gatun being similarly reached from the Atlantic side by a straight channel out to sea in Limon Bay, upon which bay Colon is situated. Practically none of this work of dredging is yet done.

Since the present plans follow a different route from that adopted by the French, the dredging accomplished by them in not now of use. The city of Panama is about two miles to the east of the

new location of the sea channel from the Sosa locks or La Boca Dam, and it is just outside the ceded territory known as the Canal Zone. It has, however, recently been given clean and well-paved streets. It possesses much of the picturesqueness of the old Spanish settlements.

On the edge of the zone at Panama, the United States government has built a large modern hotel, suited in construction to the tropics. It is on an elevated site overlooking the city and the Bay of Panama. This hotel is used by officials and engineers of the Canal Zone and their families. Here at the Tivoli, as it is called, an evening reception and dinner was tendered to the administrative force engaged in the zone by the party of visitors, at which were present the President of the Republic of Panama, the U. S. Minister to Panama, the Chief Engineer, Mr. Stevens, and others. Although Panama is but nine degrees north of the equator, the weather was all that could be desired, a clear sky, a fair breeze, and moderate temperature. The full moon rose over the bay, which happens to extend eastwardly from the city, so far as to give the effect of an open sea. Thus the Pacific ocean is to the east of Panama, to all appearances. After a comfortable night at the Tivoli, a detailed inspection was made at the site of the proposed dams at La Boca and that of the locks, there. The work of construction is soon to proceed. On the return trip to Colon a stop was made for a visit of inspection to the great storehouses at Mount Hope, formerly known as Monkey Hill, a few miles from Colon. Here there can be found, properly classified and arranged and subject to requisition, supplies and equipment of nearly all kinds outside of food; an epitome of all human needs; the product of innumerable factories of the most varied description. A catalogue of the things stored here would fill volumes. Here also were seen large quantities of stores in the form of iron and steel bars and plate left over from the French regime and largely capable of utilization in the present work.

While all along the canal route there exists an immense amount of discarded machinery known as French scrap, it would not pay at present to attempt to gather it up; the transportation facilities at command being already taxed to the utmost in the legitimate work

of construction and supply. Notwithstanding this fact, a large part of the cast iron used in the foundries in the zone is taken from the French scrap. It is possible that the light rails of the railways used by the French in construction, may become available as reënforcing material for concrete to be used in locks, or the like. Doubtless in time an opportunity may arise for collecting this valuable debris, consisting usually of high grade metal.

The question of health on the Isthmus of Panama is of vital importance in the prosecution of the work. In times past, the experience of the French company in regard to the spread of disease, and in the consequent mortality, was so bad that the region became a by-word for unhealthfulness and danger to life. This was, however, before modern methods of sanitation were known or practiced; and before the modes of transmission of the germs of malaria, yellow fever and severe intestinal disorders had become known. As soon as certain species of mosquito were known to be intermediate hosts for the organisms to which malaria and yellow fever are due, the problem of canal construction was seen to be in a large degree dependent on getting rid of these culture-charged insect pests. Throughout the Canal Zone the evidences of success in this direction are palpable. Under the direction of Colonel Gorgas, who has charge of the sanitation of the zone, it has been rendered much safer than many localities in our southern states. What menace there is, is not within the zone, but arises from the possibility of introduction from the outside. A most admirable system has been put into practice, including medical inspection, distribution of medicine, drainage, fumigation, mosquito brigades and general sanitation, such as abatement of nuisances, removal of offal and garbage, clearing of land, burning of rank vegetation, etc. The whole is a splendid example of the application of scientfic principles which might well be copied in many places. The first evidences were found at Colon in the filling in of low ground, the paving of streets and improved drainage. Again at Gatun, the tropical jungle had been cleared away almost to bare ground, especially around the habitations and where men were at work. Drainage channels had also been dug. While a few tent houses were still in use there, these were soon to be replaced by a type of dwelling now usual in the

zone, and which permits excellent sanitation and protection from mosquito infection.

These buildings are of wood, well painted, supported on posts or on pillars of concrete so as to be clear of the ground. They are of one, two or three stories in height with wide piazzas on each floor, sometimes all round, securing coolness and shade. The piazzas are screened with brass wire netting and in the sleeping apartments the usual mosquito netting is a supplemental protection. The habitations are situated on high ground, as on hills or hillsides, which can readily be kept cleared and free from pools of water. Underground drainage is provided where it is conducive to the general result.

Too much praise cannot be given to the work which has already been accomplished. The present remarkable healthfulness, the fruit of this intelligent system, is seen in the low mortality disclosed by the recent records of the zone. After all, there is no more important influence to be reckoned with in the success of the construction work, than the health and vigor of the men engaged in it. Add to the measures of sanitation, the provision of proper food and good water, together with prevention of abuse of alcoholic drinks, and it would seem that the problem of labor, even white labor, on the isthmus is solved.

It is curious to note the opinion of the men in charge as to the value of the different classes of labor of which use has been, or is now made. Negro labor, largely from Jamaica and other West India islands is rated much below white labor and the pay accorded is accordingly less. White labor from northern provinces of Spain is reported as most satisfactory and Italian labor is also looked upon with favor. It was found necessary not to entrust the negro with the choice of his own diet, as this resulted in his using only watery tropical fruits, or innutritious yams, etc., rendering it impossible for him to sustain effort, owing to actual lack of nourishment. As a result, three meals are furnished at thirty cents a day and these contain a proper balance of nitrogenous and carbohydrate constituents. He is compelled in this way to receive due nourishment and

it is said that the wisdom of this arrangement is easily seen in the work accomplished.

In Colonel Gorgas's February report to the Department of Health of the Isthmian Canal Commission, in relation to the screening of houses, occur statements to show how little the efforts in their behalf are appreciated by the negro employes. He says: "Unfortunately for the colored employees, as well as for others, the metallic screening on the buildings occupied by them is roughly treated and abused by them and has to be protected and watched." Again: "The white European laborer works much harder and more continuously than the colored employee. Aside from the clerical force, the white employee is exposed to the same conditions as the colored employees. . . . The sleeping quarters of the colored laborer and those of the white laborer are similar in every respect."

The President in his message before mentioned has referred to the fact that the colored laborer after having been brought to the zone at government expense, frequently escapes from control and resolves himself into a loafer at Colon or a jungle dweller occupying unsanitary unscreened shacks. This constitutes a most undesirable element, and even a menace from the ease of propagation of disease among such a class. Hence there is an increasing tendency to utilize desirable white labor in greater amount, and this may eventually result in a much increased proportion of whites to blacks in the zone, a proportion which has been approximately one to four hitherto.

Concerning the actual work of canal construction already accomplished under the present regime it may be said that only within the past few months has a real beginning been made. There was needed a season of preparation, arranging for sanitation, organizing the working forces, constructing buildings, storehouses, gathering supplies, and machinery. This period may now be said to have been succeeded by the opening of another one to be devoted to the shifting of huge volumes of earth and rock; the real construction period, the work accomplished in which depends directly on the maintenance of the conditions which have been so far established, and the large cost of which should be balanced by the reduction of time and expense for the actual construction of the canal proper.

There were, on March 1, according to information, between 25,000 and 30,000 men at work on the isthmus and the amount of material removed in cubic yards in the month preceding had been exceeded, so that it was thought that the figure of 1,000,000 cubic yards per month could soon be maintained.

The work itself was found to be proceeding steadily, backed by energy and earnestness of purpose of the men who were in charge. The general impression gained by the visiting body was that, with an organization such as existed under Mr. Stevens and with the improved living conditions enabling suitable labor to be secured and retained, and with modern machinery of great capacity, the progress in building the canal can be expected to continue steadily and perhaps further improvements in detail will be made. Everything depends upon maintaining an efficient organization which shall preserve the high working standard which has done so much within the past year. There is need of rational diversion and entertainment for the men employed. Schools have already been established for the children of the settlements, and it is believed are under the care of competent teachers. Athletic exercises and games, such as baseball, are resorted to for amusement and the climate is not such as to forbid moderate exertion out of doors even as pastime. While the annual rainfall at Colon is very high, ranging upto about 140 inches per annum, at Panama on the other hand it is said to be only about one third as great or about what we have along the Atlantic seaboard.

On leaving Colon for the return journey, the eight committees before referred to, utilized some of the time in preparing reports which were submitted for discussion to the whole body at meetings held for that purpose. The final result was the preparation and adoption of a combined report commending the work witnessed at the zone and the conditions which rendered it possible.

It may be too early to make predictions, for there may arise at any time serious obstacles and setbacks, but if conditions continue as favorable as they now appear to be, the completion of the great work, so important especially to the United States, should be possible within eight or at most ten years. The result of the inspec-

tion by the organized body of ninety members of the Commercial Club party is in reality an endorsement of the work of the Isthmian Canal Commission and a corroboration of the President's report to Congress after his memorable visit to the isthmus and remarkable practical examination of the work. It is a work in which every citizen should feel an interest.

THE ASSOCIATION THEORY OF SOLUTIONS.

By WILLIAM FRANCIS MAGIE.

(*Read April 19, 1907.*)

When it was discovered, by van't Hoff, that the osmotic pressure of solutions obeys the laws of gases, the conclusion was drawn, in many quarters, that the osmotic pressure is to be explained as a pressure arising from the impacts of the dissolved molecules or ions against the bounding surface of the solution, and that the part played by the solvent is simply that of a medium in which the solute is suspended, or in which it assumes a state practically equivalent to that of a gas. This conclusion was not received without opposition, especially by the advocates of the so-called hydrate theory, according to which the act of solution involves a more or less intimate or structural union of each molecule of the solute with one or more molecules of water. The trend of opinion at present is toward some form of the hydrate theory, but it does not seem to have been noticed, except by Tammann,[1] that certain properties of solutions are demonstrative against the theory of free solute and inactive solvent, and in favor of the theory that there exists such an interaction between the solute and the solvent that certain properties of the solvent are modified thereby. As the evidence which we have does not go so far as to prove the existence of true hydrates in all solutions, and indeed is rather unfavorable to the hydrate theory, as strictly construed, I prefer to call the theory based upon it the association theory of solutions.

The evidence which proves an efficient interaction between the solute and solvent, and a modification of the properties of the solvent, was discovered by Julius Thomsen.[2] On investigating the heat capacities of many aqueous solutions of electrolytes, Thomsen found that the apparent heat capacity of the solute (that is, the difference between the heat capacity of the solution and that of the

[1] *Zeits. für phys. Chem.*, Vol. 18, p. 625, 1895.

[2] "Thermod. Untersuchungen," Vol. 1; *Wied. Ann.*, 142, p. 337, 1871.

water which enters into it) becomes less as the dilution increases, and in most cases even attains a negative value, so that the heat capacity of a dilute solution is less than that of the water which enters into it. It is manifestly inadmissible to ascribe a negative heat capacity to the solute or to any part of it. It is further impossible to account for the diminished heat capacity by ascribing it to a change in the extent of dissociation due to the rise of temperature during the determination of the heat capacity, for this change has been proved to be so small as to be negligible in this connection. We are therefore forced to believe that the solute, or some part of it, interacts with the surrounding water in such a way as to diminish the heat capacity of the water.

Thomsen also found that the apparent volume of the solute (that is, the difference between the volume of the solution and that of the water which enters into it) becomes less as the dilution increases, and in a very few cases even attains a negative value. In these cases the volume of the solution is less than that of the water which enters into it. It is manifestly impossible to ascribe this result to the shrinking of the solute alone, or to an insertion of the dissociated ions in the interstices between the molecules of water. A similar inference follows to that already drawn from the behavior of the heat capacities, that the solute, or some part of it, interacts with the surrounding water in such a way as to diminish the volume of the water.

We are thus naturally led to speculate on the mode of interaction between the solvent and the solute. Tammann assumes that the effect of the solute extends throughout the solution, so as to produce an interior pressure in it, by reason of which the heat capacity of the solution is altered. He undertakes to calculate the amount of the change by the aid of a thermodynamic formula for the specific heat, involving the specific heat of the solvent under a pressure equal to the assumed interior pressure and a correction term containing the temperature coefficients of volume and pressure. Owing possibly to the difficulty of obtaining accurate data for the necessary calculations, the agreement of Tammann's calculated values with those obtained by observation is not good, though the general course of the observations is fairly well represented.

Jones[1] and his fellow workers have been led by their observations of abnormally great freezing point depressions in concentrated solutions to adopt the view that the solute interacts with the water to form groups of molecules which are so closely bound together that they move as one body in the solution. Jones calls these combinations hydrates. He explains the abnormality of the freezing point depressions by the hypothesis that the molecules of water which combine to form the hydrates are removed from the solvent so that it contains fewer free molecules or becomes more concentrated than would be inferred from the way in which the solution is made up. By following out this hypothesis he reaches the conclusion that the extent of hydration is a function of the concentration, being generally greater as the concentration increases, at least up to a certain limit.

According to our ordinary conception of the range of molecular force, we should not expect such a variable hydration as is assumed by Jones. We should expect, rather, a practically uniform action of the molecules and ions of the solute, forming groups of water molecules which are constantly the same for all concentrations; at least for those in which the groups do not frequently interpenetrate each other.

In constructing the formulas to represent the heat capacity and the volumes of solutions, I have adopted the simple conception which has just been stated. I assume that each undissociated molecule of the solute and each ion of the dissociated molecules interacts with the water around it in such a way as to change its heat capacity and its volume; these changes being the same for all concentrations to which the formulas apply. The solution, then, is considered as a mass of free and unaffected water, in which are suspended groups of water molecules, surrounding the molecules and ions of the solute, and with their properties modified by the action of the solute. It is not necessary to consider these groups as stable. Indeed it is almost necessary, if we are to account for the laws of electrolytic conduction in harmony with this hypothesis, to consider them as extremely loose and unstable aggregations,

[1] *Zeitschrift für phys. Chem.*, XLVI., p. 244, 1903; XLIX., 385, 1904.

from which water molecules are continually breaking off to be replaced by others, and through which the ions of the solute may move without dragging with them a load of water molecules. Whether the effect of the molecules and ions of the solute is to increase or diminish the heat capacity or the volume of the water in these groups, or to leave these properties unchanged, is to be determined from the values of the constants of the formulas found for each particular solute.

It should be stated that the solutions to which the formulas have been applied are made up by dissolving one gram-molecule of the solute in N gram-molecules of water. The number of undissociated molecules and the number of the dissociated ions are then expressed as fractions. They are obtained for each solution in the usual manner from Kohlrausch's tables of molecular conductivities.

The formula for the heat capacity formed on this hypothesis reduces to the sum of three terms, of which the first represents the heat capacity of the water used in making up the solution, the second is a constant multiplied by the number of undissociated molecules of the solute, the third, a constant multiplied by the number of dissociated molecules of the solute. The two constants represent the heat capacity of the molecules and ions of the solute respectively, together with the changes which they produce in the heat capacity of the groups of water molecules associated with them.

The formula for the volume assumes the same form, and, *mutatis mutandis,* the interpretation of the constants is the same as that which has just been given.

For solutions of non-electrolytes, in which there is no dissociation, the formula reduces in each case to the sum of two terms, one of which represents the heat capacity or the volume of the water used in making up the solution, and the other is a constant which depends upon the particular solute employed.

These formulas are abundantly verified by comparison with the results of observation. With regard to the non-electrolytes it has been shown[1] that the heat capacity of their solutions, in most cases, is the sum of the heat capacity of the water and of a constant characteristic of the solute. This constant in general is not the

[1] Magie, *Phys. Review,* Vols. IX., XIII.

same as the heat capacity of the solid solute. A similar rule has been shown to hold for the volumes of aqueous solutions of cane sugar by Wade and by Wànklyn, and examples of its applicability to solutions of other non-electrolytes can be obtained by simple calculations from the data given in the tables of specific gravities. The few cases in which this rule does not hold good, notably those of aqueous solutions of the alcohols, may fairly be considered as exceptions which perhaps cannot now be explained, but which we may expect to explain in harmony with our main hypothesis.

With regard to the electrolytes, the observations of Thomsen and other observations made in the physical laboratory at Princeton by Mr. R. E. Trone, can be represented by the formulas with great accuracy and completeness. As I expect soon to publish (in the *Physical Review*) an extended comparison of the data of observation with the numbers calculated from the assumed formulas, I shall content myself here with giving a few typical examples.

The formulas to be illustrated are:

For the heat capacity $H = W + A(1 - p) + Cp,$
For the volume $V = U + D(1 - p) + Fp,$

in which W and U are respectively the heat capacity and the volume of the water used in making up the solution, and p is the dissociation factor, or the number of dissociated molecules of the solute, expressed as a fraction. In the tables N represents the number of gram-molecules of water in which one gram-molecule of solute is dissolved.

The constants C and F express, for the heat capacity and the volume respectively, the effect of both ions of the dissociated molecule. Either one of them may be considered as the sum of two similar constants, each expressing the effect of one of the two ions. If, therefore, we consider solutions of two binary electrolytes, each containing a common ion, the difference between their values of C or of F should be independent of the effect of the common ion, and so should be the same for the same pair of other ions, whatever may be the common ion with which they are connected. This conclusion from the hypothesis is illustrated by the sodium and

potassium chlorides, hydrates and nitrates, for which the differences of the values of C are 22, 17, 22, and of F are 8, 9, 11.5. It is not found to hold generally true when the barium and strontium chlorides and nitrates are compared with sodium chloride and nitrate. In these cases, I am informed by Professor Hulett, there are reasons to believe that there is a double dissociation of the barium and strontium salts; in which case an agreement could not be expected.

KCl, $A = 96$, $C = -53$; $D = 47$, $F = 22$.

N	p	H M.	H Calc.	V Th.	V Calc.
15	0.672			300.4	300.2
30	.728			569.0	568.8
50	.753	880.7	882.0	928.2	928.2
150	.787	1777.6	1777.2	1827.3	1827.3
200	.818	3571.8	3572.2	3625.0	3626.0
300	.835	5370.2	5370.2		
400	.848	7167.1	7168.1		

$NaNO_3$, $A = 55$, $C = -20$; $D = 37.5$, $F = 24$.

N	p	H Tr.	H Calc.	V Th.	V Calc.
10	0.34			212.5	213
25	.514			480.4	480.7
50	.618	908.2	908.6	929.2	929.2
100	.698	1802.7	1802.7	1828.2	1828.2
200	.757	3598	3598.2	3627.0	3627.5
300	.785	5396	5396.1		

NH_4Cl, $A = 39$, $C = -23.1$; $D = 43.5$, $F = 36$.

N	p	H Th.	H Calc.	V Th.	V Calc.
10	0.593	181.6	182	219.0	219.1
25	.703	443.6	445	488.2	488.2
50	.742	893	893	937.8	937.9
100	.777	1791	1791	1837.7	1837.7
200	.806	3588	3589	3637.6	3637.5

The constant C expresses the heat capacity of the ions added to the loss of heat capacity (considered therefore as a negative quantity) of the water associated with them. The negative number obtained by adding C, which is always negative, to the negative value of the heat capacity of the ions should express the loss of heat capacity of the water associated with the ions. If we use for the heat capacity of the ions the heat capacity of the molecule com-

posed of them in the solid state, or, if this is not known, make up a heat capacity for them by adding their atomic heats, as determined by Kopp, we find that the numbers obtained, with two exceptions, fall into two groups. For one of these groups, derived from the constants for sodium chloride, hydrate, and nitrate, ammonium chloride, and hydrochloric acid, the mean number obtained is —44.8, with a maximum deviation of less than five per cent. For the other group, derived from the constants for potassium chloride, hydrate, and nitrate, barium and strontium chloride, and barium nitrate, the mean number obtained is —65.7, with a maximum deviation of less than five per cent. We may conclude from these results that the effect of ions of different sorts in diminishing the heat capacity of the water associated with them is in many cases practically the same, but that other ions may exert on the water a very different effect. The presence in one group of all the sodium salts and in the other of all the potassium salts is especially significant of this last conclusion. The differences between the effects of the ions may be represented by supposing that the action of one sort extends only so far as to affect the water molecules immediately contiguous to them, while that of the other sort extends further into the water.

It is unfortunately impossible to test the formula for heat capacity in the region of extreme dilution, but the formula for the volume has been applied to Kohlrausch and Hallwach's determinations of the specific gravity of very dilute solutions in some cases and found to hold with the constants determined from Thomsen's observations at higher concentrations. In the region of high concentration the formulas sometimes fail to reproduce the observations. This can be ascribed, I believe, to the frequent interpenetration of the groups of water molecules which are associated with each molecule or ion of the solute; or, what amounts to the same thing, to the frequent action of two or more molecules or ions of solute on the same set of water molecules.

I would explain in the same way the apparent change in the extent of hydration calculated by Jones and others from the abnormal depression of the freezing points of concentrated solutions.

The hypothesis developed in this paper does not preclude a kinetic explanation of osmotic pressure. This has been shown recently by Lowry[1] and the argument does not need to be repeated here.

The representation of the molecular conductivity as a sum of two ionic velocities, according to the theory of Kohlrausch, seems to be inconsistent with the assumption of any such action between the ions and the water as will form stable hydrates, at least if the only free electric charges present in the groups constituting the hydrates are those belonging to the ions of the solute. If, however, we assume, as has been done in this paper, that the action of the ions does not form stable groups of water molecules, but only such associations of them that the ion can pass through the water without dragging a group of water molecules with it, we can then use this hypothesis without modifying the commonly accepted explanation of electrolytic conduction.

PRINCETON, N. J., April 19, 1907.

[1] *Phil. Mag.*, April, 1907.

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THE GROUPS WHICH ARE GENERATED BY TWO OPERATORS OF ORDERS TWO AND FOUR RESPECTIVELY WHOSE COMMUTATOR IS OF ORDER TWO.

By G. A. MILLER.

(*Read April 19, 1907.*)

We shall first give two general theorems relating to commutators[1] which will be used in what follows.

Theorem I. If a commutator is commutative with one of its elements the order of the commutator divides the order of this element.

Theorem II. The smallest invariant subgroup which contains the commutator of two operators includes the commutator subgroup of the group generated by these operators.

To prove the former of these two theorems, it is only necessary to observe that if $c = s_1^{-1}s_2^{-1}s_1s_2$ is commutative with s_1 or s_2 it is also commutative with $s_2^{-1}s_1s_2$ or $s_1^{-1}s_2s_1$, respectively. Hence s_1 or s_2 would be commutative with $s_2^{-1}s_1s_2$ or $s_1^{-1}s_2s_1$, respectively. The proof of the theorem follows now from the facts that the order of the product of two commutative operators divides the least common multiple of their orders, and that the orders of the two factors in the present case are the same. The proof of the second theorem follows from the fact that the two operators in question would correspond to commutative operators in the quotient group with respect to the given invariant subgroup. In particular we have the corollary, *If two operators generate a group the conjugates of their commutator generate the commutator subgroup.*

Let s_1, s_2 be any two operators of orders 2 and 4, respectively, which satisfy the conditions

$$s_1^2 = 1, \quad s_2^4 = 1, \quad s_1s_2^2s_1s_2 = s_2^3s_1s_2s_1,$$

[1] The principal known theorems relating to commutators are found in two articles published in the *Bulletin of the American Mathematical Society*, vol. 4, p. 135 and vol. 6, p. 105.

and consider the four operators

$$s_1s_2^3s_1s_2, \quad s_1s_2s_1s_2^3, \quad s_2^3s_1s_2^3s_1s_2^2, \quad s_2^2s_1s_2^3s_1s_2^3.$$

The common product of the two commutators and of the other two factors is $s_2^3s_1s_2^2s_1s_2^3$. Hence each of these four factors transforms this common product into its inverse. Moreover, the common product of the first and third and of the second and fourth of the four given operators is $s_1s_2^2s_1s_2^2$, and each of these operators transforms this common product into its inverse. From this it follows that the two operators

$$s_2^3s_1s_2^2s_1s_2^3 \text{ and } s_1s_2^2s_1s_2^2$$

are commutative and that the group generated by them is either cycle or the direct product of two cyclic groups. This abelian group, together with $s_1s_2^3s_1s_2$, generates a group (H), which involves $s_1s_2s_1s_2^3$, $s_2^3s_1s_2^3s_1s_2^2$, $s_2^2s_1s_2^3s_1s_2^3$. The order of H cannot be more than twice that of the given abelian subgroup, and H is invariant under the group (G) generated by s_1 and s_2, since s_2 transforms the four generators of H among themselves and s_1 transforms the first two of them into themselves, while

$$s_1s_2^3s_1s_2^3s_1s_2^2s_1 = s_1s_2^3s_1s_2 \cdot s_2^2s_1s_2^3s_1s_2^3 \cdot s_2s_1s_2^3s_1.$$

From theorem II we conclude that H is the commutator subgroup of G and we have the preliminary theorem: If a group is generated by two operators of orders 2 and 4, respectively, whose commutator is of order 2, the commutator subgroup must be of one of the following two types: the cyclic group of order 2, the group obtained by extending a cyclic group or the direct product of two cyclic groups by means of an operator of order 2 which transforms each operator of this direct product into its inverse.

The group generated by H and s_1 is invariant under s_2, since it contains $s_2^3s_1s_2$. Hence the order of G cannot exceed eight times that of H. As the operators of odd order in G (if such operators occur) generate a characteristic subgroup of its commutator subgroup the order of the commutator quotient group is either 4 or 8; that is, the order of G is either four or eight times that of H.

The octic group is clearly the group of smallest order which contains two operators of orders 2 and 4, respectively, whose commutator is of order 2. In this case the commutator subgroup is cyclic and the commutator quotient group is the four-group. There is one group of order 16 which is generated by two operators of orders 2 and 4, respectively, whose commutator is of order 2. This may be defined as the group of order 16 which involves the abelian subgroup of type (1, 1, 1) and 4 cyclic non-invariant subgroups of order 4. In this case the commutator subgroup is again cyclic and the commutator quotient group is of type (2, 1). Since this group of order 16 has a (2, 1) isomorphism with the octic group, and since the operators of odd order in G generate a characteristic subgroup, it follows that *every group which is generated by two operators of orders 2 and 4, respectively, whose commutator is of order 2, has the octic group for a quotient group, and its commutator quotient group is either of type* (1, 1) *or of type* (2, 1).

Suppose that the commutator quotient group of G is of order 4. If the order of G were divisible by 16 it would have the group of order 16 considered in the preceding paragraph as a quotient group. This is impossible since the commutator quotient group of the latter is of type (2, 1). That is, *if the commutator quotient group of G is of order 4 the order of G is $8m$, m being an odd number.*

If H contains an invariant cyclic subgroup whose order exceeds 2, the operators of H, which are commutative with a generator of this subgroup, constitute an invariant subgroup of G. This invariant subgroup does not include $s_1s_2^3s_1s_2$, and hence it does not include H. Since the group of isomorphisms of a cyclic group is abelian and every invariant subgroup which gives rise to an abelian quotient group includes H, the assumption that H contains an invariant cyclic subgroup whose order exceeds 2 has led to a contradiction. From this it follows that the groups generated by $s_2^3s_1s_2^2s_1s_2^3$ and $s_1s_2^2s_1s_2^2$, respectively, have at most 2 common operators and that these cyclic groups are either of the same order or the order of one is twice that of the other. In particular, if the order of G is divisible by an odd prime number p, the highest power of p which divides this order has an even index. The main results

which have been obtained may be expressed as follows: *If a group is generated by two operators of orders 2 and 4, respectively, whose commutator is of order 2, the commutator subgroup is either the cyclic group of order 2, or it may be constructed by extending the direct product of two cyclic groups, involving the same odd factors, by means of an operator of order 2, which transforms each operator of this direct product into its inverse.*

It should be observed that the Sylow subgroups whose orders are powers of 2 in the factors of the direct product of the preceding theorem are either of the same order or one of these orders is twice that of the other. In particular, this direct product may be of order 2. In this case H is the four-group. When H is abelian its order can clearly not exceed 8, and when it involves operators of odd order its order cannot be less than 18. The octic group and the given group of order 16 are evidently the only possible groups when H is cyclic and the substitution group of order 64 and degree 8 which may be generated by $s_1 = ae$, $s_2 = abcd \cdot efgh$ is a group in which G has its largest possible value when H is abelian. As an instance of a G which involves operators of odd order we may mention the transitive group of degree 6 and of order 72. This may be generated by $s_1 = ae$ and $s_2 = abcd \cdot ef$, and is the smallest possible group involving operators of odd order, which may be generated by two operators of orders 2 and 4, respectively, whose commutator is of order 2.

Let s_2 be a substitution of degree $2p$, p being any odd prime number, involving only one transposition. Representing s_2 by $a_1a_2a_3a_4 \cdot b_1b_2b_3b_4 \cdot \ldots l_1l_2l_3l_4 \cdot mn$ and s_1 by $a_3b_1 \cdot b_3c_1 \cdot \ldots l_3m$, it is clear that s_1, s_2 generate a transitive group of degree $2p$. As the order of H is divisible by p^2 and as it contains a direct product of two cyclic groups whose orders are divisible by p, this direct product must be of order p^2. The order of H is therefore $2p^2$ and H is obtained by establishing a (p, p) correspondence between two dihedral groups of order $2p$. Since s_2^2 is not commutative with any substitution in the direct product of order p^2 contained in H besides the identity, it has p^2 conjugates under this direct product and hence transforms each one of its substitutions into its inverse. From this it

follows that $s_2^2$and this direct product generate H, and hence the order of G is $8p^2$. We have thus arrived at an interesting infinite system of transitive groups of degree $2p$ and of order $8p^2$, such that each group is generated by two substitutions of orders 4 and 2, respectively, whose commutator is of order 2.

As an indirect result of the preceding paragraph we have that the group of isomorphisms of the abelian group of order p^2 and type (1, 1) must always include the octic group. As the abelian group of order p^m, $m > 2$, and of type (1, 1, 1, ...) can be made simply isomorphic with itself after any correspondence has been established between two of its subgroups, it follows from the above that *the octic group is a subgroup of the group of isomorphisms of the abelian group of order* p^m, $m > 1$, and of type (1, 1, 1, ...), *p being any odd prime number.* In particular, this group of isomorphisms contains two operators of orders 2 and 4, respectively, whose commutator is of order 2.

The main results of the preceding paragraphs may be stated as follows: If G is generated by two operators of orders 2 and 4, respectively, whose commutator is of order 2, then G is solvable and has an $(a, 1)$ isomorphism with the octic group. The commutator quotient group of G is of order 4 or 8. When this order is 4 the order of G is $8m$, m being an odd number, and vice versa. The highest power of an odd prime factor of the order of G has an even index and the Sylow subgroup of this order is the direct product of two cyclic subgroups of the same order. When the commutator subgroup of G is cyclic G is either of order 8 or of order 16 and vice versa. The only other abelian commutator subgroups which may occur in G are the four-group and the abelian group of order 8 and of type (1, 1, 1). The other possible commutator subgroups of G may be obtained by extending the direct product of two cyclic groups by means of an operator of order 2 which transforms each operator of this direct product into its inverse. A cyclic subgroup whose order exceeds 2 which is contained in this direct product is not invariant under G.

UNIVERSITY OF ILLINOIS,
January, 1907.

JONAH'S WHALE.

By PAUL HAUPT.

(*Read April 20, 1907.*)

In my paper on "Archæology and Mineralogy," which I read at the general meeting four years ago,[1] I remarked that a competent archæologist must have more than a bowing acquaintance with all branches of science. His philological equipment enables him merely to read the records of the past; but even the translation of an ordinary historical text presupposes a large amount of knowledge, not only of philology, history, chronology, geography, ethnology, but also zoology, botany, mineralogy, &c. I pointed out some conclusions which I had reached, on the basis of mineralogical considerations, with regard to two importantant problems in archæology, *viz.* King Solomon's Mines and Alexander the Great's Expedition to the East. I showed that the *lilies* of the Bible were dark purple sword-lilies (*Gladioli atroviolacei,* Boiss.)[2] which the ancients called *hyacinths,* a name which they used also for the purple variety of quartz, which we term *amethyst,* while the *amethyst* of the ancients denoted the rare purple variety of corundum, known as *purple ruby* or *amethystine sapphire.* I also showed that the *stones of Tarshish,* mentioned in the Bible, were ruby-like crystals of cinnabar from the quicksilver mines of Almaden in southern Spain, and that *Tarshish* was a Phœnician word meaning *dressing of ores,* especially *spalling.*[3] Tarshish was the mining region in southern Spain, and the *ships of Tarshish* went to Spain,

[1] See the abstract in the *Johns Hopkins University Circulars,* No. 163, p. 51.

[2] See *Haupt, Biblische Liebeslieder* (Leipzig, 1907) p. 34, n. 20; *cf.* n. 34 to my paper *Difficult Passages in the Song of Songs* in the *Journal of Biblical Literature,* Vol. XXI., p. 68, and my notes on the Book of Canticles in *The American Journal of Semitic Languages,* Vol. XVIII., p. 241.

[3] See Haupt, *Bibl. Liebeslieder,* p. 59, n. 37; *cf.* the *American Journal of Semitic Languages,* Vol. XVIII., p. 230, and the *Verhandlungen des xiii. Orientalisten-Kongresses* (Leyden, 1904) p. 232.

and not to India.[1] The prophet Jonah was commanded to go to the East, to preach repentance in Nineveh; but he boarded a vessel at Joppah, and tried to go West, to Tarshish, *i. e.*, southern Spain.

In the present paper I shall discuss a zoological problem, *viz.* Jonah's whale. Geo. A. Smith has prefixed to his remarks on the Book of Jonah the quotation:[2] *And this is the tragedy of the Book of Jonah, that a Book which is made the means of one of the most sublime revelations of truth in the Old Testament should be known to most only for its connection with a whale.* Jonah's whale is the sea-monster which *swallowed up* the disobedient prophet and *vomited him out* again *upon the dry land,* after Jonah had been in the bowels of the monster three days and three nights. The original text speaks only of *a great fish,*[3] just as the legend of the Fall of Man speaks only of the *fruit* of the *tree of the knowledge of good and evil,* not of an *apple*.[4] Not to know good and evil (*i. e.*, what is wholesome and injurious) means in Hebrew to be like a child. He who eats of the forbidden fruit loses his childlike innocence. The Fall of Man is the first coitus—an explanation which was given by the great English philosopher Thomas Hobbes in his *Leviathan* (London, 1651).[5]

The popular conception that Jonah was swallowed by a whale is based on the passage Matt. xii, 39–41, where Jesus says: *An evil and adulterous*[6] *generation seeketh after a sign; and there shall no sign be given to it, but the sign of the prophet Jonas.*[7] For as Jonas was three days and three nights in the whale's belly; so shall

[1] See p. 119 of the Critical Notes on the Hebrew text of the Book of Kings in the Polychrome Bible.

[2] In Vol. II. of *The Book of The Twelve Prophets* (London, 1898) p. 492 (*The Expositor's Bible*).

[3] The preceding verb does not mean *prepared* but *detailed, appointed; cf.* Haupt, *Purim* (Leipzig, 1906) p. 17, l. 37.

[4] The Hebrew word for *apple* seems to denote the large yellow berries of the mandrake; see Haupt, *Bibl. Liebeslieder,* p. 64; *cf.* the *American Journal of Semitic Languages,* Vol. XVIII., p. 232, n. 5.

[5] See my remarks in the *Journal of Biblical Literature,* Vol. XXI., p. 66.

[6] That is, *idolatrous.*

[7] The wonderful message of God transmitted by Jonah and Jesus is sufficient; *cf.* Luke xi, 30; xvi, 31; also Mark, viii, 12.

the Son of Man[1] be three days and three nights in the heart of the earth. *The men of Nineveh shall rise*[2] *in judgment with this generation, and shall condemn it*,[3] *because they repented at the preaching of Jonas; and behold a greater than Jonas is here.* That is, the Ninevites had more faith than the present generation: when a prophet of Israel preached in a foreign land to the heathen inhabitants of Nineveh, they believed him and turned to God; Jesus, a greater prophet than Jonah, *came unto His own* home, *and His own* people *received Him not* (John i, 11).[4] Matt. xii, 41 is the immediate sequel of v. 39; the intervening verse is a later insertion.[5] Even if these words were authentic, they would not prove that Jesus regarded the history of Jonah as actual history. We may illustrate a point by referring to King Lear without committing ourselves as to the historical accuracy of Shakespeare's tragedy. An astronomer who speaks of a beautiful sunset does not contest the Copernican system.

The Greek text has in Matt. xii, 40 κῆτος (Lat. *cetus,* which means *sea-monster,*[6] but not necessarily *whale*). Any huge marine animal might be called *cetus,* not only a cetacean, but also a large cuttle-fish, or a huge shark, or the enormous sea-serpent, which is said to have been repeatedly seen at sea.[7]

[1] *Son of Man* means simply *man* in Aramaic; see the translation of *Ezekiel,* in the Polychrome Bible, p. 96, l. 51; *cf.* Wellhausen, *Israelitische und jüdische Geschichte* (Berlin, 1904) p. 387, below.

[2] In the Revised Version: *stand up.* For the phrase *to stand in the judgment* see Psalm i and my explanation in *The American Journal of Semitic Languages,* Vol. XIX., p. 132.

[3] That is, if the Ninevites were tried together with this generation for disbelief in revealed religion, they would be acquitted, and you would be found guilty: they would *stand* the test, and you would be found wanting.

[4] *Cf.* Gustav Frenssen's *Hilligenlei,* chapter XXVI., p. 523.

[5] In Luke xi, 29–32, there is no reference to Jonah in the belly of the whale; *cf.* Wellhausen, *Das Evangelium Matthæi* (Berlin, 1904) p. 64.

[6] The Revised Version gives *sea-monster* in the margin. In Gen. i, 21; Job vii, 12, on the other hand, the R. V. substitutes *sea-monster* for the rendering *whale* in the Authorized Version.

[7] The accounts given of the appearance of the so-called *sea-serpent* cannot all be based on inaccurate observations, though it is not certain that this unknown sea-monster is an animal of serpentine form. The President of the *Deutsche Orient-Gesellschaft,* Admiral Hollmann saw a large *sea-serpent* on July 26, 1883; *cf.* A. C. Oudemans, *The great sea-serpent* (London, 1892) and the article, *Das Problem der grossen Seeschlange* by Dr. R. Henning in the Berlin weekly *Daheim* (1906) No. 49.

Some scholars imagined that Jonah merely dreamed that he had been swallowed by a great fish. Others fancied that the prophet was not swallowed, but clung to the belly of the fish.[1] Certain expositors suppose that The Whale was the name of a ship which picked up Jonah, or the name of an inn on the seashore.[2] The famous German student's song (by Scheffel) begins: *Im schwarzen Walfisch zu Askalon da trank ein Mann drei Tag,* and the last stanza is: *Im schwarzen Walfisch zu Askalon wird kein Prophet geehrt, und wer vergnügt dort leben will, zahlt bar was er verzehrt.*

Orthodox theologians who defend the historical character of the Book of Jonah generally presume that the great fish which swallowed Jonah was a shark.[3] Professor Geo. E. Post, of the American College, Beyrout, Syria, saw a shark at Beyrout 20 feet long, and they sometimes attain a length of 30 feet.[4] Sharks may swallow men, and even horses and other large animals whole. In certain theological commentaries[5] we find the remarkable statement that, in 1758, a sailor fell overboard in the Mediterranean and was swallowed by a shark (*carcharias*). The captain commanded to train a gun upon the man-eater, and the monster was hit by a cannon ball. The shark vomited out the sailor who was picked up by a boat; he had hardly suffered any injury. This is reported to have happened in 1758; I did not see it.

Against the traditional rendering *whale* the objection is often raised that there are no whales in the Mediterranean,[6] and that the

[1] See Hastings' *Dictionary of the Bible,* Vol. II. (New York, 1899) p. 749[b], below.

[2] See J. D. Michaelis' translation of the Old Testament, Part XI. (Göttingen, 1782) p. 100.

[3] *Cf.* C. F. Keil's Biblical commentary on the Minor Prophets (Leipzig, 1873) p. 285.

[4] See Hastings' *Dictionary of the Bible,* Vol. IV. (New York, 1902) p. 914[b].

[5] See Paul Kleinert in J. P. Lange's *Bibelwerk,* part XIX. (Bielefeld, 1868) p. 30[a]; Keil's commentary, p. 285, below.

[6] The daily papers stated on March 24, 1907, that the Rev. A. C. Dixon, of Chicago (who caused comment by his declaration that the Biblical story of Jonah and the whale was perfectly true, and that the Deity could have constructed the whale along the lines of a modern submarine vessel with electric lights and a cabin), when told that whales were never seen in the Mediterranean, replied: There was one there in the early days.

gullet of the whale is not large enough to admit a man. Now there can be no doubt of the existence of whales in the Mediterranean, although the Swedish naturalist and traveler Fredrik Hasselquist states in his *Voyages and Travels,* published in 1766,[1] with reference to Job xli, 1, where the Authorized Version has *whale* in the margin for *leviathan*:[2]—*How could he speak of an animal which never was seen in the place where he wrote, and at a time when he could have no history of Greenland and Spitzbergen.* Dr. Post states that large parts of the skeletons of two specimens of the right whale are preserved in the museum of the Syrian Protestant College at Beyrout. One of these animals was cast up on the shore near Tyre, not far from the traditional site of the ejection of Jonah, which is at *Nabî Yûnus* (Arab. *Khân an-Nabî Yûnus*)[3] near Zidon. The other was drifted ashore at Beyrout itself. The gullet of the *right whale* would not admit a man; but the *sperm-whale*[4] or *cachalot*[5] has a gullet quite large enough to enable him to swallow a man. Sperm-whales are found in the Mediterranean, although they are not frequent.

[1] Hasselquist's *Iter Palæstinum, eller Resa till Heliga Landet* was edited by Linné (Stockholm, 1757). Hasselquist died at Byn Bagda near Smyrna in 1752.

[2] Leviathan = crocodile, behemoth = hippopotamus.

[3] The tomb of the prophet Jonah is shown at *Al-Máshhad* (i. e., *Tomb of a Saint*) representing the Biblical *Gath-hepher* (2 Kings xiv, 25) north of Nazareth; also in the south near the ancient fortress of *Bethsura* (north of Hebron) whose unsuccessful siege (163 B. C.) is alluded to in Eccl. iv, 14; see Haupt, *Ecclesiastes* (Baltimore, 1905) p. 42, n. 6. *Nabî Yûnus* is also the name of the smaller mound southeast of the Acropolis of Nineveh; see my address on the Book of Nahum in Vol. XXVI of the *Journal of Biblical Literature* (p. 2) and *cf.* Bædeker's *Palästina und Syrien* (Leipzig, 1904) pp. 102, 216, 241, 361.

[4] The name *sperm-whale* or *spermaceti whale* is derived from the *sperm-oil* or *spermaceti* found in the cavity of the head of the cachalot. This oily white liquid, which solidifies on cooling, was called *sperma ceti,* because it was regarded as the male spawn (or *milt*) of the animal. Dutch and English whalers formerly called spermaceti *whale-shot.* It is also known as *white amber;* see below.

[5] *Cachalot* is a French loanword. In the new Oxford dictionary *cachalot* is derived from a Romanic word for *tooth,* Gascon *cachau,* Carcassonne *caichal.* The *cachalot* is not a *mysticete, i. e.,* a *baleen* or *whalebone whale,* commonly known as *right whale,* but an *odonticete* or *denticete, i. e.,* a toothed cetacean.

[6] See Hasting's *Dictionary of the Bible,* Vol. IV., p. 914[b].

In a cuneiform inscription of the Assyrian king Assur-nâçir-pal (885–860 B. C.) we find the statement that his predecessor Tiglath-pileser I (about 1100 B. C.) boarded Phœnician ships at Arvad (near the N. E. end of the Mediterranean) and slew a *blower,* just as the German Emperor a few years ago, during one of his Norwegian cruises, took part in a whale-hunt. The Greek name of the sperm-whale, *physeter,* means *blower,* i. e., spouting up water.[1] In a paper on the cuneiform name of the cachalot (which I read at the annual meeting of the American Oriental Society held in Philadelphia, April 5, 1907)[2] I showed that the *blower* (Assyr. *nâkhiru*) slain by the ancient Assyrian king in the N. E. part of the Mediterranean must have been a *sperm-whale,*[3] because in a passage of the cuneiform annals of Assur-nâçir-pal we read that this Assyrian king received, as tribute from Tyre, Zidon, Arvad, and other places on the Phœnician coast, ivory *teeth of the blower, the creature of the sea.* This *blower* with ivory teeth cannot have been a *narwhal*[4] or *walrus;*[5] these animals are not found in the Mediterranean. The sperm-whale has, on each side of the lower jaw,[6] from 20 to 25 conical (slightly recurved) teeth which consist of the finest ivory. They are about 5 or 6 in. long, projecting about 2 in. from the gum. The upper jaw, which is very much larger than the lower jaw, is destitute of teeth; at any rate the upper teeth are quite rudimentary and buried in the gum.

[1] The *blowing* or *spouting* of a whale is the act of expiration; the visible stream is chiefly condensed vapor like that of human breath on a cold day.

[2] See the *American Journal of Semitic Languages,* Vol. XIII., p. 253.

[3] The blow-hole of the cachalot is near the edge of the snout.

[4] The so-called *horn* of the *narwhal* (which is sometimes ten feet long and which consists of the hardest ivory) is the left upper incisor of the animal, just as the tusks of elephants are incisors. The horn of the *unicorn* in the British royal coat of arms is the tusk of a narwhal; see my remarks in the translation of the Psalms, in the Polychrome Bible, p. 173.

[5] The enormous teeth which protrude like tusks from the upper jaw of the male walrus are canines, just as the large ivory teeth of the hippopotamus, which sometimes reach a length of two feet or more and weigh upward of six pounds.

[6] The scientific name of the *sperm-whale* is *Physeter* or *Catodon macrocephalus. Catodon* means *having under teeth. Macrocephalus* points to the enormous size of the square head of the cachalot, which represents one half of the entire bulk of the animal and about one third of the total length.

For several centuries ivory was known as *whale's bone* (not *whalebone!*). Shakespeare says: *To show his teeth as white as whale's bone.*[1] The comparison *as white as whale's bone* is proverbial in the old poets. Also the very hard (*petrosal*) parts of the ear-bones of whales resembles ivory, just as the substance of the ear-stones (*otoliths*) of fishes is called *brain-ivory*.

In the second column of the obelisk recording the slaying of a sperm-whale in the Mediterranean at the hands of Tiglathpileser I (about 1100 B. C.) Assur-nâçir-pal (885–860) states that he placed two *blowers* of AD-BAR-stone at the gates of the palaces in the ancient capital of Assyria, *Assur*, now known as *Kileh Shergat*[2] where the Germans have been conducting excavations during the past four years under the auspices of the *Deutsche Orient-Gesellschaft*. According to No. 26 of the *Mitteilungen* of this Society (Berlin, April 1, 1905) p. 56, the ideogram AD-BAR means *basalt*, and on p. 53 of the same number the field-director of the German excavations at Kileh Shergat reports that a great many basalt fragments of sculptures have been found, but the restoration of the figures has not been accomplished. Assyriologists did not know that *nâkhiru*,[3] blower meant *sperm-whale*. It is not impossible that the two basalt cachalots of Kileh Shergat will eventually be recovered. The general color of a sperm-whale is a very dark

[1] *Cf.* H. H. Furness' *Variorum Shakespeare*, Vol. XIV.: *Love's Labour's Lost* (Philadelphia, 1904) p. 262.

[2] Arab. *Kal'at Shergât;* see Bædeker's *Syrien und Palästina* (1904) p. 362, l. 5.

[3] Hommel, in his *Geschichte Babyloniens und Assyriens* (Berlin, 1889) p. 532, deemed it possible that the *blower* which Tiglathpileser I slew in the northeastern part of the Mediterranean was a hippopotamus! English Assyriologists explained *nâkhiru* to mean *dolphin*. But the *blower* must have been an exceptionally large and dangerous animal, and comparatively rare in the Mediterranean; otherwise the slaying of this one animal would not have been especially recorded. It seems to have been regarded as the greatest achievement in Tiglathpileser's venatic record, for this feat is mentioned first, before the accoûnt of Tiglathpileser's hunting of wild oxen, elephants, lions, &c. The hunting of a cachalot is a much more hazardous undertaking than ordinary whaling. When aroused, the sperm-whales are formidable adversaries. They can completely destroy a whaleboat by crunching it with the teeth or striking with the tail, and by using the enormous head as a ram they can sink small vessels like the ships of Arvad on which Tiglathpileser I embarked.

grey, nearly black on the upper parts, and lighter beneath. The ancient Assyrian sculptors might have imitated this by the use of dark grey and light grey dolerites, or light dolerite and dark anamesite. In the reports of the *Deutsche Orient-Gesellschaft* the stone is called *Basalt lava.* This is very indefinite: any kind of basalt might be called *basalt lava;* all the rocks of the basalt family are of eruptive origin.

The basalt cachalots of Kileh Shergat are probably very large. The giant sperm-whale attains a length of about 100 feet, with a girth of 40 feet. The Arabic name of the sperm-whale[1] is *'ambar* (for *'anbar, 'abbar*) which means *passing through the water;* Heb. *'ovér yam* (Is. xxiii, 2) means *seafaring, passing over the sea. 'Anbar* is also the name of the fragrant substance which we call *ambergris,* i. e., *grey amber,* in distinction from yellow amber (French *ambre jaune,* German *Berustein,* i. e., *lapis ardens*)[2] and *white amber,* i. e., *spermaceti.* While a pound of (purified) spermaceti is worth about 30 cents, grey ambergris is worth about $35.00 per oz. at present;[3] this (wholesale) price is subject to considerable variation. The use of ambergris in perfumery is decreasing. Ambergris is a morbid concretion from the alimentary tract of the sperm-whale, like the *bezoar*[4] found in the stomach and intestines of certain animals, especially the wild goat, *Capra Ægagrus,* known as the *bezoar goat,* which is found chiefly in the mountains of the Caucasus and Persia. The fragrance of ambergris is said to be due to a bacterium, the *spirillum recti physeteris.* Ambergris is usually found floating on the surface of the ocean or cast upon the shore in regions frequented by sperm-whales, sometimes in masses from 60 to 215 pounds in weight. The sperm-whale is most abundant off New Zealand, in the Sulu Sea, about the Cape Verde Islands, and in the Indian Ocean. Roughly speaking we may say that the cachalot is found chiefly betweet lat. 40° N. and 60° S. The

[1] See Hommel, *Die Namen der Säugethiere bei den südsemitischen Völkern* (Leipzig, 1879) pp. 393 and 447.

[2] See my remarks in the *American Journal of Semitic Languages,* Vol. XXIII., p. 242, l. 5.

[3] Black ambergris is cheaper: the wholesale price is $20.00 per oz. at present.

[4] Bezoar is a corruption of the Persian *pâdzáhr* (Arab. *bâdizahr*) a compound of *pâd,* expelling, and *zahr,* poison.

region of Arvad where Tiglathpileser I slew a sperm-whale is S. of lat. 35° N.

In the Ethiopic Bible the name *'anbar* is used for the *great fish* which swallowed Jonah. A sperm-whale might have swallowed the disobedient prophet, but it is, of course, impossible that Jonah should have been alive after having been in the belly of the whale for three days and three nights, although it is reported in the *Neue Luther. Kirchenzeitung* 1895, p. 303, that a whaleman, James Bradley was, in Feb. 1891, swallowed by a whale, and on the following day he was taken alive out of its stomach. He lay in a swoon in the belly of the whale. The sailors had much difficulty in restoring him to consciousness. It was not till after three months' nursing that James Bradley recovered his reason.[1]—After all, he seems to have been more fortunate in this respect than some distinguished Biblical scholars.

We need not trouble ourselves about the miraculous preservation of the prophet: the Book of Jonah is not actual history, but an apologue like the story of the good Samaritan in the New Testament (Luke x, 30–37) or the parable of the three rings[2] in Lessing's *Nathan der Weise*. The Book of Jonah (which may have been composed, like *Ecclesiastes*,[3] under the reign of Alexander Jannæus, about 100 B. C.) represents a Sadducean[4] protest against the Pharisaic exclusiveness based on the conviction that Divine Grace was reserved for the Chosen People, not for the Gentiles. The present Book of Jonah seems to have displaced in the Dodecapropheton a prophecy of the ancient prophet Jonah ben-Amittai, of Gath-hepher, who prophesied (about 785 B. C.) at the time of King Jehoahaz of Israel (*cf.* the Deuteronomistic addition in 2 Kings xiii, 4–6) the deliverance of Israel from the oppression of the Syrians, which was accomplished by Jehoahaz's son, Jeroboam II (see 2 Kings xiv, 25).

[1] See Hasting's *Dictionary of the Bible*, Vol. II., p. 750[b].

[2] This was taken from Boccaccio's *Decamerane, Giornata i, Nov. iii: Melchisedech Giudeo.*

[3] See Haupt, *Ecclesiastes* (Baltimore, 1905) p. 1.

[4] *Sadducee*, righteous is a euphemistic term for *unrighteous*, i. e., *Hellenizer, freethinker;* see Haupt, *Ecclesiastes*, p. 35, n. 1, and the paper *The name Istar* in the *Journal of the American Oriental Society*, Vol. XXVIII.

The sea-monster which swallowed Jonah corresponds to the wonderful creatures in the Arabian Nights, which transport men to the remotest regions. We must assume that the whale swallowed Jonah near Joppa and cast him ashore at Alexandretta. It was easier for Jonah to proceed thence to Nineveh, especially if he went down the Tigris, than to return to Jerusalem.[1] A sperm-whale could easily swim from Joppa to Alexandretta in three days and three nights; the distance is only about 300 miles. The cachalot swims, as a rule, at a rate of from 3 to 7 miles an hour, and just under the surface of the water. If a sperm-whale swam seven miles an hour, it might rest more than nine hours a day and still cover the distance from Joppa to Alexandretta in three days and three nights, *i. e.*, 72 hours. If Jonah had traveled overland on horseback, it would have taken more than two weeks. The trip from Joppa to Haifa, which represents but one sixth of the entire distance from Joppa to Alexandretta requires from two to three days. A day's journey on horseback is about 25 to 30 miles. The gait of the horses in Palestine is a brisk walk; they hardly ever trot.

The sea-monster was suggested to the author of the Book of Jonah by the local legends connected with Joppe.[2] According to tradition, Andromeda was chained to the rock on the southern side of the narrow opening in the low ledge of rock forming the harbor of Joppa. Andromeda was there exposed to a sea-monster, but was rescued by Perseus, just as the Trojan princess Hesione was delivered by Hercules from a marine monster. The myth of

[1] The overland journey from Alexandretta to Diârbekr (through Aleppo and Urfa) may be made in about 10 days, and the rafting on the Tigris from Diâbekr to Nineveh requires but four days, when there is plenty of water (*i. e.*, from April to June). Ancient Assyrian rafts, supported by inflated skins, and modern *keleks* on the Tigris are figured on pp. 124 and 125 of the translation of *Ezekiel* in the Polychrome Bible.

[2] Cheyne remarks in his *Encyclopædia Biblica* (col. 2574, below) that the sea seemed more alive near Joppa than elsewhere, and the living power in certain waters was frequently held to be derived from serpents or dragons. In Babylonian mythology the dragon *Ti'âmat* is the personification of the primeval ocean. The ocean was imagined as a broad circular stream encircling the disk of the earth; see my paper *The Rivers of Paradise* in the *Journal of the American Oriental Society*, Vol. XVI., p. ciii, and my remarks on the Babylonian map of the world in the translation of *Ezekiel* (in the Polychrome Bible) p. 100, l. 35.

Perseus and Andromeda reappears in the legend of the patron saint of England, St. George[1] and the Dragon in connection with the city of Beyrout in northern Syria. The Bay of Beyrout is known as St. George Bay, and the belief in a hugh sea-monster is still rife there. The Chaplain to the Church of Scotland at Beyrout, Geo. M. Mackie, states[2] that when a few years ago a Belgian steamer reaching Beyrout at midnight blew her siren whistles to inform the agents of her arrival, the unprecedentel shriek, which startled the whole town out of sleep, was supposed to be the howling of the marine monster, and next day the chief topic of conversations in the bazaars was the visit of the *beast of the sea* during the previous night.

Josephus[3] and Pliny[4] state that the holes where the staples of Andromeda's chains had been driven into the rock were shown at Joppa, and Pliny relates that the bones of the sea-monster to which Andromeda is said to have been exposed were brought from Joppa to Rome and exhibited with a number of other curiosities under the edileship of Marcus Scaurus (58 B. C.). This skeleton was 40 feet long; the ribs were larger than those of the Indian elephant, and the spinal column was about 1½ feet thick.[5] This is preceded by the statement that a sea-monster is said to have been cast ashore, near Cadiz in Southern Spain, which measured 16 cubits between the ends of the flukes and had 120 teeth from 6 to 9 in. long.[6] Sixteen Roman cubits would be about 23 feet,

[1] St. George is said to have been a tribune (of Cappadocian extraction) in the Roman army at the time of the Diocletian persecution of the Christians, who, about 303 A. D. was put to death in Nicomedia.

[2] See Hastings' Dictionary of the Bible, Vol. II, p. 755[a], n. †.

[3] Bell. Jud. III., 9, 3: *ἐνθα τῶν 'Ανδρομέδας δεσμῶν ἐτι δεικνύμενοι τύποι πιστοῦνται τὴν ἀρχαιότητα τοῦ μύθου. Cf.* Strabo, §759: *ἐνταῦθα δὲ μυθεύουσί τινες τὴν 'Ανδζομέδαν ἐκτεθῆναι τῷ κήτει.*

[4] *Nat. Hist.*, v, 69: *Iope Phoenicum, antiquior terrarum inundatione, ut ferunt, insidet collem præjacente saxo in quo vinculorum Andromedæ vestigia ostendunt; colitur illic fabulosa Ceto. Cf.* Ovid, *Metamorph.* iv, 670.

[5] Plin. *Nat. Hist.*, IX., 11: *Beluæ cui dicebatur exposita fuisse Andromeda ossa Romæ apportata ex oppido Judææ Iope ostendit inter reliqua miracula in ædilitate sua M. Scaurus, longitudine pedum XL, altitudine costarum Indicos elephantos excedente, spinæ crassitudine sesquipedali.*

[6] *Turranius prodidit expulsam beluam in Gaditano litore cujus inter duas pennas ultimæ caudæ cubita sedecim fuissent, dentes ejusdem CXX, maximi dodrantium mensura, minimi semipedum.*

and the flukes of a giant sperm-whale may be 23 feet between their extremities, although 12 to 15 feet is a more frequent measurement. The teeth of a sperm-whale are, as a rule, 5 or 6 inches long, not 6–9 inches, and the number 120 appears to be due to a misunderstanding: the original report may have been that this marine monster had 60 teeth on both sides of the lower jaw, which may have been misinterpreted to mean: sixty teeth on each side of the lower jaw. As a rule, a sperm-whale has from 20 to 25 teeth on each side of the lower jaw, according to the age of the animal. Pliny says of the *physeter*, i. e., the *sperm-whale:* it is the largest animal in the Gallic ocean, *i. e.*, the Bay of Biscay. It raises itself like an enormous pillar, towering above the sails of the vessels[1] and spouting a flood of water.[2] Cachalots often raise their enormous square head above the water, and the head of a giant sperm-whale may be more than 30 feet long.

There is no reason for doubting the statement that there were some chains fastened to one of the rocks near the entrance to the port of Joppa; nor is there any reason for discrediting the report that the skeleton of a sea-monster was brought from Joppa to Rome in 58 B. C. A large sperm-whale may have been drifted ashore at Joppa, and the skeleton may have been left there for a long time until it was finally carried to Rome at the time of Cicero. The legend of the maiden exposed to the sea-monster and rescued by a gallant hero is a subsequent embellishment of popular fancy,[3] suggested by the presence of the huge skeleton on the beach, and the author of the Sadducean apologue known as the Book of Jonah

[1] The masts of ancient vessels were not very high. A terra-cotta model of a Phœnician ship is figured in the translation of *Ezekiel* (in the Polychrome Bible) p. 149.

[2] Plin. *Nat. Hist.* IX., 8: *Maximum animal . . . in Gallico oceano physeter ingentis columnæ modo se attollens altiorque navium velis diluviem quandam eructans.*

[3] *Cf.* the legend of King Bodo and Brunhildis in connection with the granite cliff, known as *Rossmannshöhe,* in the Hartz mountains, and the legend of the *pillar of salt* in the story of Lot (Gen. xix, 26; Luke xvii, 32). See the picture of the pillar of salt at Usdum facing p. 308 of Lynch's *Narrative of the U. S. Expedition to the River Jordan and the Dead Sea* (Philadelphia, 1850).

introduced the sea-monster (or giant-sperm-whale) of Joppa in order to transport the disobedient prophet as speedily as possible from Joppa, the sea-port of Jerusalem, to Alexandretta, the terminus of the shortest route from the Mediterrenean to Nineveh.

The grotesque idea that the prophet composed an elaborate poem in the belly of the whale must not be credited to the author of the story. Even Luther said, Jonah hardly felt so well as to sing so fine a song.[2] This psalm is a later insertion, just as the Song of Hannah (in the Books of Samuel)[3] and Moses's Song of Triumph (in the Book of Exodus).[4] The editor who inserted the psalm in the Book of Jonah misunderstood the metaphorical expressions *sea, ocean, surge,* and *billows,* which are used in Hebrew for *distress, disaster,*[5] and which refer here especially to the Syrian persecution at the time of Antiochus Epiphanes (about 168 B. C.).[6] This Maccabean poem, which has no connection whatever with the legend of Jonah, may be translated[7] as follows:[8]

A i 2 When in distress I called,
JHVH responded;
From depths of Sheol I cried;
My voice was heard.

That is, whenever Israel was in distress, JHVH heard their prayers,

[1] The theory that the *great fish* which swallowed Jonah was a *cachalot* was advanced by Quandt, *Jonas der Sohn Amithai* (Berlin, 1866) cited (but rejected) by Paul Kleinert in J. P. Lange's *Bibelwerk,* part XIX. (Bielefeld, 1868) p. 28, below.

[2] *Sowohl ist ihm nicht gewesen, dass er hätte mögen solch ein feines Liedlein singen.*

[3] See my paper *The Prototype of the Magnificat* in the *Journal of the German Oriental Society,* Vol. LVIII (Leipzig, 1904) p. 617.

[4] See my paper in the *American Journal of Semitic Languages,* Vol. XX., p. 154.

[5] Shakespeare says: *deep-drenched in a sea of care* and *what a tide of woes Comes rushing on this woeful land at once!*

[6] See n. 23 to my translation of the Book of Nahum in Vol. XXVI. of the *Journal of Biblical Literature* (p. 17).

[7] Lines and words omitted in the present translation represent subsequent additions; see my restoration of the original text in the *American Journal of Semitic Languages,* Vol. XXIII., p. 256.

[8] The rhythm of my translation has been much improved in a number of passages by the kind assistance of the distinguished coeditor of the Polychrome Bible, Horace Howard Furness.

even when Israel seemed to be annihilated for ever at the time of Nebuchadnezzar.

ii 3 Thou plungedst me into the sea,
The ocean engulfs me;
Thine every surge and billow
Over me they pass.

This refers to the Syrian persecution at the time of Antiochus Epiphanes.

B iii 4 I thought, lo! I am banished
From thy presence for ay;
How again shall I see
Thy Holy Temple!

It seemed as though the religion of the Jews was to be exterminated for ever; even the Temple on Mount Zion was in the hands of the heathen for three years, until it was reconsecrated by Judas Maccabæus in Dec. 165.[1]

iv 6 To the depths of the sea, I descended,
To perdition[2] for ay;
Tangle enveloped my head,
Sheol's[3] bolts barred me.

Israel was almost submerged and drowned; Hellenic culture threatened to engulf and bury Judaism for ever.

C v 7 When in me my soul fainted,
I thought on JHVH;
To Thee my prayer arose,
To Thy Holy Temple.

When Judaism was *in extremis*, the Maccabees began their holy war, and their faith was gloriously rewarded by JHVH.

vi 8 Who worships false follies,[4]
Forsakes his boon;[5]
9 But I with songs of praise
Sacrifice to Thee.

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[1] See my explanation of Ps. xxiii in the *American Journal of Semitic Languages*, Vol. XXI., p. 152.

[2] Lit. *to the earth*, i. e., the *netherworld*, Hades.

[3] Lit. *her* bolts, referring to the netherworld.

[4] That is, the Greek gods.

[5] God's love and grace.

COMPARISON OF LATITUDE OBSERVATIONS AT SAYRE OBSERVATORY, SOUTH BETHLEHEM, AND AT FLOWER OBSERVATORY, PHILADELPHIA,

FROM SEPTEMBER 30, 1904, TO SEPTEMBER 3, 1906.

BY JOHN H. OGBURN.

(*Read April 20, 1907.*)

This paper is based on two years work on latitude determination at Bethlehem compared with that obtained during the same period at Flower Observatory, the results of which Professor Doolittle has kindly furnished me in advance of publication.

The Sayre Observatory at South Bethlehem, under Professor Doolittle's direction, was among the first to be devoted to this class of work and the observations, continuing through a period of nearly twenty years, resulted in a series which has been an invaluable aid in the discussions of the laws of the variation of latitude. It was thought that a continuation of the same class of work for some years might be desirable as it would result in a longer series at a given point than could be found elsewhere.

To aid in this project, the late Mr. Robert H. Sayre, one of the trustees of Lehigh University, furnished the means for procuring a modern zenith telescope and a suitable house for it.

The zenith telescope house was erected in the spring of 1904 according to plans which conform to those of the International Latitude Stations and is composed of wood excepting the roof which is of tin. The walls are double, with an air space of one foot between the inside ceiling and the latticed extérior. The inside dimensions are, 10 feet square with walls 7 feet high. The roof is divided in the middle and the two halves move on pinions giving a maximum opening of 6 feet. The object glass of the telescope, when pointing to the zenith, is about 2 inches below the top line of the walls.

The pier is composed of concrete, the top face being 27 inches square, and rises from a foundation of the same material in the form of a cube whose dimensions are 5 feet, placed wholly beneath the surface of the ground.

The zenith telescope is from the work-shop of Warner and Swasey, the optical parts by Brashear. The clear aperture of the object glass is 4½ inches, its focal length 48 inches and is furnished with electric illumination. The base and vertical axis are of massive construction. It maintains its position in adjustment with little variation. A magnifying power of 144 has been employed throughout. No record of errors in azimuth, collimation and level has been kept. The sum of these corrections for any star of the observing list during the period embraced by these observations was always less than one second of time.

The observations were made with a view of determining a value for *the Constant of Aberration* according to the plan suggested by Dr. Küstner of Berlin. This entails the grouping of the greater part of the observations around four periods in the year which include about eight months altogether, but their distribution is such that the results are equally available for investigating the variation of latitude. The method of conducting the observations has been identical with that followed at Flower Observatory. Since the two stations are practically on the same meridian and the declinations of the stars are eliminated, the two series are directly comparable.

At Bethlehem the list of stars comprise 4 groups of 10 pairs each and the usual adjustment of each observed latitude to the mean latitude which would result from the average of the 80 stars' declinations have been made. Observations for investigating the effect of temperature on the micrometer value were made by two methods and the final results for the temperature coefficient for the two years are in such close agreement as to inspire some confidence in their trustworthiness. These values for the two years, in units of the sixth decimal place are 146 and 138. The individual determinations are so discordant, however, that I have not considered their introduction into the reductions advisable, since the average correction for the micrometer for any group of stars is less than one

revolution. The probable error of latitude from one pair of stars —the part due to observation alone—for the two years was ± 0″.121 and ± 0″.112 respectively.

The following work is an attempt to find whether the abrupt deviation at irregular intervals of the observed latitude from the mean value by an amount many times its probable error at *Bethlehem* is duplicated in a greater or less degree at *Philadelphia*.

Thus, at Bethlehem the observations gave for the ten pairs

	40° 36′ 20″ +				
May 21, 1906	3″.58	3″.54	3″.56	3″.74	3″.80
On next observing night	3 .88	3 .83	3 .92	3 .74	3 .94
The differences	+0 .30	+.29	+.36	+00	+.14

					Mean
3″.60	3″.78	3″.74	3″.75	3″.74	3″.68
3 .99	3 .84	4 .12	3 .82	4 .10	3 .92
+.39	+.06	+.38	+.07	+.36	+.24

The first values give a latitude agreeing closely with the finally deduced value for that date; therefore the difference, 0″.24 represents a departure from the mean of 7 times the probable error.

By applying the average difference between the two stations to the latitude at Philadelphia we can construct a diagram which very nearly represents the efforts of two independent observers to follow the motion of the pole at a given meridian. (Page 170.)

The observations at each place for any day on which no corresponding observations at the other place were made have been omitted so that the diagrams represent about half the observations at Philadelphia and two-thirds those at Bethlehem.

The two curves agree pretty closely as to the lengths of the periods and total variation, but the maximum and minimum values at Philadelphia fall about three weeks earlier than the corresponding phases at Bethlehem.

Two methods will be employed in the comparisons.

First Method.

The observations were divided into periods of about forty days each and the means of the latitude for each of these periods found. The simple difference was taken between the latitude for each group

and the mean of the corresponding forty day group in which it is found and the result for each station tabulated side by side.

Omitting all record of groups where the observations were less than 4, there remian for comparison 209 groups which give the following results.

Cases where one or the other residual was zero = 27.
Cases where both residuals were greater than 0″.15 = None.
Cases where both greater than 0″.10 = 10 : — 7 "like," 3 "unlike."
Cases where smaller residual was > 0″.05 and < 0″.10 = 62 : — 35 "like," 27 "unlike."
Cases where smaller residual was between 0″.00 and 0″.05 = 109 : — 54 "like," 55 "unlike."

An actual departure at both places from the mean latitude in the same direction should manifest itself in the majority of cases by an agreement of sing in these residuals. This is actually found in the case of the residuals greater than 0″.10 but the total number of cases is too small to have much weight. Irrespective of the magnitude of the residuals there are 96 "alike" and 85 "unlike." If the two series of observations were entirely independent the theory of probability would require that the number of "like" and "unlike" be 90 each and the difference between this and the actual numbers is so small the inevitable conclusion follows that the two series are practically independent.

Second Method.

Excluding all work in which a determination at either place on any night depends on the observations of less than six pairs there remain 123 common dates which represent 3,410 separate determinations, 1,730 at Philadelphia and 1,680 at Bethlehem. By constructing to a generous scale the diagram just shown on the screen and drawing smooth curves for the two sets of observed latitudes we may consider these curves as the actual values of the latitude during the period represented in this comparison and the differences between the latitudes at each station and the value derived from the curve will give us a set of residuals which should be a measure of the precision of one night's work on the supposition that the variation is represented by long periods.

Let ΣV_1^2 and ΣV_2^2 be the sum of the squares of the residuals at Philadelphia and Bethlehem respectively. Evidence of systematic fluctuations would be shown if $\Sigma V_1^2 + \Sigma V_2^2$ is appreciably greater than ΣV_3^2 where ΣV_3^2 is the sum of the squares of the residuals derived directly from the differences of the observed latitudes.

These last residuals must be derived in a way that will eliminate the systematic divergence resulting from an apparent constant difference in the times of maxima and minima at the two places. This has been effected by considering V_3 as the algebraic difference between V_1 and V_2. Without reproducing the details the following results were found.

$$\Sigma V_1^2 = 0''.5706$$
$$\Sigma V_2^2 = 0\ .6993$$
$$\Sigma V_3^2 = 1\ .2718$$

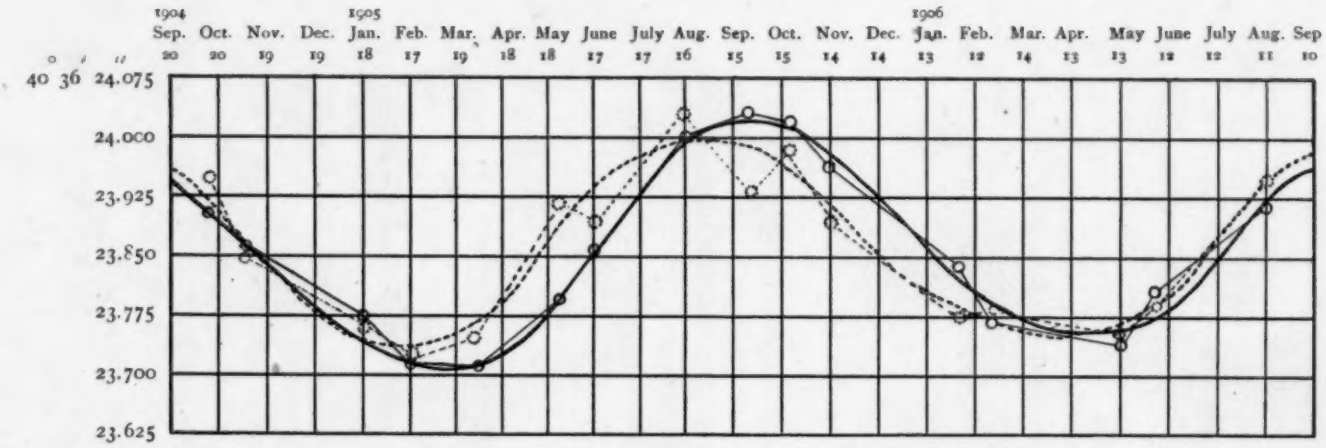
Since $\Sigma V_1^2 + \Sigma V_2^2$ differs from ΣV_3^2 by less than $0''.002$ it is evident that these observations show no relation between abnormal values of observed latitude at the two stations.

If the residuals are reduced to probable error there results:

For one night's determination from 10 pairs—

at Philadelphia $\pm 0''.053$: For one pair $\pm 0''.17$.
at Bethlehem $\pm 0\ .057$: For one pair $\pm 0\ .18$.

The part in this latter due to observation alone was nearly $\pm 0''.12$ leaving $\begin{matrix}\pm 0''.13 \\ \pm 0\ .14\end{matrix}$ at the two places for the probable error of one observation which is apparently beyond the observer's influence.



Graphical representation of the variation of latitude as observed at the Flower Observatory, Philadelphia, and the Sayre Observatory, South Bethlehem.

NOTE.—The latitudes of Flower Observatory have been increased by 38′ 21″.744, the mean difference in latitude between the stations.

Dotted curve.—Philadelphia.

Full curve.—South Bethlehem.

TRANSPORTATION IN THE UNITED STATES.

By LEWIS M. HAUPT.

(*Read April 19, 1907.*)

When, in the early dawn of Friday, October 12, 1492, the natives of the Isla Guanahani, saw three phantom caravels bearing down upon their homes, it is said, they were so amazed that they ran to cover and exclaimed, "*Nous sommes Decouvert.*"

Possession was immediately assumed by Columbus in the name of Spain and the possibility of thus acquiring great wealth and dominion by the right of discovery, stimulated many adventurers to cross the Atlantic, but no permanent settlements were effected until the Spanish established a colony at St. Augustine, Florida, August 28, 1565, and the English at Jamestown, Virginia, under Captain John Smith. in April, 1607.

Then followed several centuries of colonial governments with their incidental contests for trade and territory and confiscation of native right until the conditions became so intolerable as to compel a confederation for mutual defense which finally led to the formation of the republic on the seventeenth day of September, 1787.

Up to this date, the resources of the country being exhausted by war, and the population greatly scattered, little attention could be given to any general plan for the conduct of domestic commerce although a few of the states had made explorations and granted charters for the building of canals and the improvement of rivers.

One of the earliest of these was the project endorsed by the American Philosophical Society, for the creation of a waterway between the lakes and the seaboard, which was surveyed and recommended by Provost Wm. Smith and David Rittenhouse, both of this Society, in 1770, leading to the construction of the Schuylkill and Susquehanna Canal some years after. In 1785 Washington was made President of the Potomac Company to connect the Chesapeake Bay with the Ohio River and on January 5, of the following year, the James River and Kanahwa Canal was incorporated.

The discovery of coal in Pennsylvania in 1792 greatly stimulated the opening of canals in the middle and eastern states under corporate control, and in a few instances the government became interested by subscribing to the stock of the companies, as in the case of the Dismal Swamp, the Chesapeake and Delaware, the Louisville and Portland canals.

Thus fostered and encouraged the mileage of the canals increased rapidly and on safe commercial routes, so that up to the date of the Civil War there were over 5,000 miles in operation estimated to have cost $150,000,000 while in the same time the general government had expended less than $15,000,000 on its waterways.

With the incoming railroad epoch, in 1830, the trend of investments changed and as the roads soon discovered their inability to compete with the cheaper water routes, maintained by the states, and also to pay a tax on their tonnage, a war of extermination was waged and in time these ancient servitors of the public were forced to the wall.

These primitive railways, operated at first by horses and later by small wood-burning engines, followed the canal routes as being those of least resistance and greatest traffic, but carried very little freight, and efforts were made to restrict their business exclusively to passengers, but it was not successful.

Thus along the line of the Erie Canal there were nine independent railroads; the first of which extended from Albany to Schenectady, opened in September, 1831, or six years after the canal. These links were subsequently united and in 1851 the Hudson River road was completed and an all rail connection made over this route with the lakes.

Similarly the Pennsylvania Railroad was built from Columbia up the Susquehanna and Juniata to Hollidaysburg, thence crossing the mountain on the old Portage Railroad to the Conemaugh at Johnstown and thence to Pittsburg via. the Kiskiminitas and Allegheny. The total distance from Philadelphia was about 395 miles by this route. The railroad was opened through to Pittsburg, December 10, 1852, and soon after, the improvement of the Ohio was urged by the president of the company as the best method of increasing the traffic of his lines.

The Baltimore and Ohio was also pressed westward along the Potomac, following closely the lines of the Chesapeake and Ohio Canal to Pittsburgh and Wheeling, which latter was completed in 1851 at a cost of $11,071,000. The railroad was opened to Harper's Ferry, 82 miles, in 1834 at a cost of $4,000,000. When extended to Chicago, 795 miles, the capital reached $57,000,000.

The Delaware and Raritan Canal, which was controlled by Commodore Stockton, was so bitterly opposed by John Stevens who was applying for a charter for the Camden and Amboy Railroad that it was found only possible to secure either by a consolidation of the two companies requiring both to be completed and opened at the same time.

From these early beginnings the contest between the two systems for the internal traffic of the country waxed warm and the higher speed and greater latitude of the railroads enabled them to tap the business at its sources and retain it at the expense of the canals. Frequently where this could not be done, the canals were leased for long periods of years and the tonnage diverted even at a heavy charge for the maintenance of the canal. Such leases by common carriers, exercising the rights of eminent domain, should never have been authorized as they are clearly against the public interest and in restraint of trade.

So rapidly has this extermination of the waterways proceeded that in this great commonwealth where there were 1,084,87 miles in operation, in 1872, it was reduced to only 217 miles (as reported by the census of 1889) while the last report of the Secretary of Internal Affairs states: "At the time of the sale of the public works many years ago, it was in the contract of the sale that the canals should be kept open by the purchaser for the convenience of the people in the transportation of their productions."

"The canal of Pennsylvania is a reminiscence. It is not easy to discover the bed of the old canal. The levelling process is rapidly filling up its trenches and the young growth of timber has obscured its location." Then follows the very significant remark that: "The average receipts per ton mile upon all the railroads are very much lower than they were when the canals of Pennsylvania were all in operation," and also the average rates on the New York

Central and Hudson River Railroad which is in competition with the enlarged Erie Canal, are so much higher than those on the Pennsylvania Railroad, that had the latter been able to charge the New York rates on the business of last year, "its increase in freight revenue alone would have been upwards of six and a half million dollars."

From which it is concluded that Pennsylvania does not need canals to secure low rates.

These data point inevitably to the fact that because of her waterway the state of New York is enabled to secure a lower rate on a large part of her crude materials, and supply her mills and factories without requiring the railroads to carry so much of this class, at about cost, to keep the wheels of industry in motion, and that in consequence the railroads have a larger tonnage of higher class freight and are making more money. Under this exhibit would it not be good policy for the railroads of Pennsylvania to expend some six millions annually for a few years to enable them to increase their revenues permanently by not less than that amount? In fact a prominent official stated only last week that what Pennsylvania needed most for transportation was the restoration of her abandoned canals.

There is an inherent difference between the railroad and other systems of transportation which enables its managers to control it absolutely, and although it is supposed to be built by public funds under state and government laws, the public has little or nothing to say as to its policy or control. In fact, its own board is never sure it has the control of its property, if large blocks of its securities are on the market. But the patricular feature to which attention is directed is the impossibility of any one shipping his own goods, in his own vehicle, and at his own convenience as is the case with a waterway, or a road. This feature makes it possible to so control the movements of freight as to have led in the past to many and serious irregularities, discrimination, rebates, special charges for terminal facilities, demurrage, warehousing, failures to supply cars, and many other acts in restraint of trade.

The railroads should be regarded as a public trust and not a device for the acquisition of great wealth for those in control. It

is also unwise to attempt to fix rates by legislation since the physical conditions, traffic and character of business and population are the principal elements in the adjusting of tolls which can best be determined by the integrity of the officers in charge.

In a recent lecture on railroad safety devices, Mr. J. C. Irwin, superintendent of construction of the New York Central Railroad stated that "the tremendous prosperity in this country is certainly the cause of the chief troubles in the operation of our roads at the present time. The traffic has increased so rapidly that the efforts to increase facilities have not been able to keep up with it. 'The increase in trackage has been almost nothing in comparison to the tremendous increase in freight tonnage. The large expenditures for modern freight yards have often resulted in little more than additional storage room for cars, mainly from lack of sufficient main line trackage or of properly located warehouse facilities. This overwhelming business has also manifested itself in the demoralization of the operating force. The rates of pay have been constantly increased yet the demand for skilled labor makes it almost impossible to get enough good men for the service."

This is not a recent discovery, however, for as long ago as 1892 the president of the Pennsylvania Railroad stated that there was then a larger amount of tonnage tendered to the railways than they were properly able to handle, while at the same time the competition between the transportation lines of the country was more active and the traffic carried at lower rates than at any other period of their history. From these statements it should not be expected that relief will be secured by legislation reducing the maximum tariffs as this would have the double effect of driving some of the smaller lines out of business and also increasing the tonnage on those that remained, resulting in greater delays and risks.

To ascertain just where the weak spot is located an analysis has been prepared of the most important elements of this problem showing the increments of population, tonnage, trackage, equipment and yardage, from which it appears that the railroads are absolutely unable to meet the present demands of traffic, with no possibility of providing for the future excepting by a radical modification of their policy of absorption, by the substitution therefor

of one of segregation and dispersion to the waterways, as soon as they may be put in condition for the traffic which has been diverted for so many years, and for the maintenance of which the National appropriations, although large, have been wholly inadequate and inefficient.

Mr. J. J. Hill has repeatedly shown so forcefully the impossibility of meeting the demand for the additional trackage that it is hardly necessary to reiterate, save for the record. He said "The traffic of the country is congested beyond imagination. The commerce of the country is paralyzed, and continued, it means slow death." The money required to restore the equilibrium would be more than double the whole amount in circulation and the entire capacity of all the rolling mills could not furnish the stock even if the men and the money were at hand. This is certainly a critical condition and so he recommends a canal down the Mississippi valley from St. Louis to the gulf, as a measure of relief. Has this great and experienced railroad president drawn on his imagination? Far from it he has pointed out the only possible remedy which the physics of the country affords, namely the subdivision into trunk line water routes with short tributary rail deliveries to numerous local points of distribution, and the substitution of the vessels of much larger capacity for the small car-units which cannot be handled to advantage. The system must also be one which can be operated throughout the entire year and therefore its outlets should be in latitudes below the winter frosts, as much as possible.

But to return to the data and their deductions, and for convenience arranging them in tabular form for the decade 1895–1905, there follows:

ELEMENTS OF THE TRANSPORTATION PROBLEM.

Population.

	1895	1905	Increase.	Per Cent.
United States.	69,500,000	86,100,000	16,600,000	23.5
		Trackage		
Single track.	177,746	216,973	39,227	22
2d, 3d and 4th track.	12,348	19,881	6,533	53
Yards and sidings.	43,181	69,941	26,760	62
Total tracks.	233,275	306,796	73,521	31

Tonnage Carried.

Tons.	755,799,883	1,435,321,748	679,521,865	90
Ton-miles, etc.	83,567,770,801	187,375,621,537	98,807,850,736	111
Tons per mile.	4,362	6,681	2,418	57

Rolling Stock.

Locomotives.	36,610	49,616	13,006	35
Freight cars.	1,230,798	1,757,105	526,307	43
Tractive Power.	13,700	28,700	15,000	109
Freight car capacity increased over				120
Tons per capita.	10	15	5	50
Tons-miles capita.	1,160	1,000	840	72

Thus while the mileage has not even kept pace with the increase of population the tonnage has multiplied five fold. This has been met by increasing the number and capacity of the freight cars as well as the weight and tractive power of engines, requiring in many instances large expenditures for betterments in track and equipment.

But still the cars accumulate in yards and sidings and it is found that while the actual average haul of 130 miles can readily be covered in eight hours after the train is made up that the delays in the loading, unloading, assorting and storing of these multitudinous units requires from six to eight days which reduces the actual efficiency down to only about six per cent. To increase the number or capacity of the cars would not relieve the congestion, but as about one half of the tonnage is coal and ore it would be greatly simplified if these products were carried on the restored water channels which they once followed at lesser cost to the consumers.

It is worthy of note that this enormous railroad system for the carriage of interstate commerce, has been developed mainly by the contributions of moneys from public and private investors, amounting to more than sixteen and a quarter billions of dollars, entrusted to corporations, exercising the rights of eminent domain under state and national authority, and it has covered the populous sections of the country with such a ramification of roads as to leave little opportunity for additional, independent lines to be built. In the more sparsely settled west the increase is still progressing with the result of adding more traffic to the already engorged roads as

well as to the length of haul, if the present Atlantic ports are to hold the trade. But the ratio of the growth in the mileage is rapidly decreasing for in the several decades ending with the years, as stated, the percentages of increase in main line mileage was as follows:

1845, 323%; 1855, 295%; 1865, 291%; 1875 111%; 1885, 73%;
1895, 41%; 1905, 21%;

showing that the construction of track is relatively losing very rapidly, as compared with the ratio of growth in population, and especially in tonnage; for within the next generation the population of this country, which is increasing more rapidly than any other civilized nation, will have doubled.

The total tons of freight carried on all lines in 1905 was 1,435,321,748 carried at an average charge of 0.784 cents making the total tax paid for rail transportation per ton for the average distance of 130.4 miles amount to $1,469,518,157. The cost of handling this freight before and after reaching the railroads is no doubt as much more, and in addition there are many other charges to be met between the producer and consumer, so that the total tax on overland commerce is probably not far from $3,000,000,000 annually.

Very great economies might be effected if any considerable amount of this traffic were carried by water and the average rail haul were reduced. Unfortunately the internal channels are not available, although the government has been struggling with this problem for over forty years and in some instances for nearly a century and a brief analysis of progress seems to be necessary as a guide to future possibilities. For this purpose the best authorities are the official reports of the departments and the records of Congress as to expenditures and results. Numerous organizations have sprung up all over the country demanding far greater liberality from the national government for waterway improvements and the president of the National Waterways Congress who is himself an agressive member of the House Committee on Rivers and Harbors, in a recent speech, said in substance:

"Some of our most worthy projects have been under way for a great many years and are still far from completion. He then cites the Harlem River, under the shadow of Wall Street under

consideration for 28 years at an estimated cost of only 2,700,000, less than half of which is expended, yet the commerce passing last year was estimated at more than $270,000,000. Over twenty years ago Congress began the opening of the Warrior and Tombigbee rivers to the greatest coal mines on earth. The improvement was estimated to cost $3,000,000; it has subsequently been modified and the estimate doubled, so that it will be many years before it is completed and made available.

The subject of improving the Ohio has been under consideration for more than a century . In 1817–18 the state of Pennsylvania began work to be carried as far as Wheeling. In 1835 Congress applied $550,000 to the river for the 600 miles above the falls at Louisville, and began removing snags and rocks but abandoned it after a few years. The Pennsylvania Railroad organized a corporation to effect its improvement but the government intervened as with other parties and it was not until 1875–6 that the system of movable dams was finally determined upon for this stream and work commenced by the government, in an effort to secure a six-foot stage by such structures, at an estimated cost of some $50,000,000. "It has proceeded with a snail's pace," said Mr. Rausdell. "Out of 52 locks of this system only six have been completed and four others are in process of construction. The project has been changed to one of 9 feet and the estimate increased to $63,000,000. If this gigantic and most meritorous work is continued at the same rate as for the past thirty years it will not be closed at the end of this century."

Long before that date the traffic will be demanding not less than 14-feet, as Chicago is now doing from the lake to the gulf, and as the state of New York demands to hold her trade against the enterprising Canadians who have so wisely enlarged their St. Lawrence canals to over 20 feet and are now proposing the Georgian-Bay-Ottawa route to save still greater distances and costs.

After enormous expenditures in efforts to deepen the Mississippi and frequent changes of plans and personnel there is a possible gain of three feet in the depths below Cairo, secured by the transient method of hydraulic dredging, which does not remove the sediment from the bed but merely shifts it from the shoals for the time

being, requiring a large plant to be maintained for use during low stages only.

The total expenditures of the Government for works of this class since the Civil War have exceeded $545,000,000 which, with the exception of the 20-foot channel in the Great Lakes, has effected no commensurate result and there would appear to be no possible relief in sight under the jurisdiction of the present régime for many years. Certainly no corporate body could hold its own under such an exhibit of expenditures and results. There appears to be but one solution, namely, a return to the early policy under which the waterways of the country were developed by corporations holding state or national charters, when there was little difficulty in securing capital for the local improvements under control of competent local directors, familiar with the needs of their people. The hopelessness of getting the Ohio River open for the greatest manufacturing district in this country, if not in the world, within a reasonable time has stimulated many of Pittsburgh's most enterprising and far-sighted citizens to apply for state and national charters to construct a ship-canal across the lake divide so as to secure a 14-foot water communication with the outer world as soon as practicable. Although no national aid was sought, it took about ten years merely to obtain this consent, but now the project is fairly on its feet, so far as the rights are concerned it should prove to be one of the most valuable and important adjuncts in relieving the engorgment of that section, and be pushed with all possible dispatch to completion. As it is but little more than 100 miles across this lowest divide, the work should be completed in about six years.

In view of the past experience of the improvement of our rivers and harbors under national control it is an undeniable fact that the progress is interminably slow and the results unsatisfactory. The trunk lines are barely improved at all, after more than fifty years of operation, and other isolated improvements are of little or no avail for general transportation purposes. Some of the harbors have been deepened after enormously heavy expenditures made for jetties which did not improve but were auxiliary to dredging, which must be relied upon with increasing expenditure for maintenance. Our own river, the Delaware, has not yet secured a 26-foot channel

at mean low water, nor is the harbor at its mouth a satisfactory refuge for large vessels. The great harbor of New York has but 30-feet at low water and vessels are obliged to await the tides to cross the bar while all the large dredging contractors have withdrawn their plants from the works.

In short it is hopeless to look for relief from this source, for the entire works of the country, and it is essential that the states should again resume their sovereignties and authorize corporations to make the much needed improvements within their borders and also compel the surrender of long time leases where the traffic has been withdrawn, so that manufacturers and others may again receive fuel and raw-material at water rates and with much greater dispatch.

One firm in the Pittsburg district thus saves nearly $1,000,000 annually on its coal bill alone because of the Monongahela River rates by water.

The Internal Improvement Commission of Illinois closes a very strong appeal for the opening of the lakes and gulf waterway in these practical and timely words:

"There is every reason for the State of Illinois to earnestly lead in the promotion of a National Waterway policy, and there is also reason for her to set an example to sister states in a domestic waterway development. When the United States has adopted a systematic policy, we must expect the national function to be restricted to the broad outlines and arteries of a system and that local waterways and ports will be relegated to the states. Meantime it may be worth while to consider whether the state of Illinois, should not undertake the development of the route through the state, receiving from the United States such subsidy as it may choose to give. There may be hidden wisdom in such self-reliance as has marked the state of New York, and it may be that the influence of two such states will be sufficient to lead the Federal government into a National Waterway policy."

The committee might have added that Massachusetts, New York, Pennsylvania and Ohio are also moving along the same lines in the inauguration of their great works independently of government aid and, in some cases, exercising the right to collect tolls from the trade, as on all railroad-transportation routes under corporate control.

Twenty-two years ago it was reported to Congress that "The manifest destiny of the country points unerringly to the emancipation of the waterways as the next great work, not of war but of peace." Why is it not yet accomplished?

THE PRINCETON UNIVERSITY ARCHÆOLOGICAL EXPEDITION TO SYRIA.

By HOWARD CROSBY BUTLER.

(*Read April 19, 1907.*)

In a paper of this length I can do no more than present a rough outline of the work of the Princeton Expedition to Syria, and dwell upon a few of the more important sections of its work.

The Princeton Expedition of 1904–5 was organized to carry on and supplement the work of the American Expedition to Syria in 1899–1900. Both expeditions comprised four departments, one for surveying and making maps, one for the study of architecture and the other arts, one for Greek and Latin epigraphy and one for Semitic epigraphy. These four departments, with the exception of that for surveying, were in charge of the same four men on both expeditions.

The country explored is more narrowly defined as Central Syria, comprising, in the south, the country far east of the Jordan, the Haurân and the regions south and east of it, namely the ancient Roman Province of Arabia; and, in the north, the country between the river Orontes and the Euphrates, extending as far north as Aleppo; this comprises the ancient Provinces of Syria Prima and Euphratesia. The district between these two regions, comprising Damascus and its vicinity, is better known and less important for archæological research.

These two great tracts, with the exception of the Haurân, are entirely, or for the most part, desert, and are consequently uninhabited except for occasional bands of nomads. They are thus so much the better for the work of archæologists, for the reason that, having been deserted for some thirteen centuries, they have known only natural changes since the beginning of the seventh century. Our explorations were confined almost exclusively to the deserted localities.

The barren wastes of central Syria are not to be thought of as flat and sandy plains; the region is mountainous in most parts, though, as one goes further east, the hills are lower and the country becomes more of a rolling nature. The mountain districts, where the most important remains are found, present a formation not unlike our own Berkshires in Massachusetts, or the mountains of Pennsylvania, but where our own hills are covered with verdure and capped with forests, the hill country of Central Syria is stripped of soil, devoid of verdure, barren of forests and practically waterless. The north is a rocky, mountain waste of limestone, naked to the sky; the south is a rolling sea of black basalt.

This whole region, now sparsely settled or wholly deserted, was, in ancient times, the seat of a highly developed civilization, and thickly populated. There are extensive remains here of cities, large and small, of military posts and excellent roads, all in a remarkable state of preservation, witnessing to the former wealth and impor- completely exposed for the examination of the explorer, and their tance of this desert land. These remains are not buried; they stand state of ruin has been brought about solely by earthquakes.

A hundred questions arise as to how a fertile country could be reduced to the condition of a desert in fifteen hundred years, and a long paper, even a book, might be prepared, attempting to give an explanation. All that I can say now is that there is abundant evidence to prove, first, that the region was thickly settled—twenty large sites, all deserted, can be counted from the top of one high hill; second, that there was soil where now there is none, for the hillsides were terraced up with high walls behind which there is now hardly a cupful of earth; third, that there was water in the stream beds that are now always dry—aqueducts, washing places, bridges and stepping stones show this; fourth, that grapes and olives were extensively grown, for thousands of wine and oil presses are to be found near the deserted towns; and fifth, that wood was abundant, for timbers of large size were too extensively employed in the architecture to permit of their having been imported. Whatever other agencies may have operated to reduce this country to its present state, I believe that the cutting of forests aided and hastened the end.

These parts of Syria have been but little explored; few of the sites visited by our expedition appear upon any map. The pioneer explorer was the Marquis de Vogüé, who published maps of two small sections of the country, together with one hundred and fifty drawings of architecture, as the result of his journey in 1860–61. Since that time no systematic explorations have been carried on here, though occasional travellers have crossed the region at one point or another. And, though the great high-road between Damascus and Aleppo passes through the northern district, there are important sites within a few miles of it, on either side, that have never been recorded, and probably never visited, by Europeans since the Roman legions were withdrawn. The maps made by our surveyors will add the names of forty ancient towns and a far larger number of smaller sites to the map of Syria, will show the courses of ancient streams and roads, and will thus contribute to Syrian cartography.

A great body of monuments of architecture is being published from the measured drawings, notes and photographs made by our expedition. The earliest building with a definite date belongs to the second century, B. C., though there are undoubtedly some of the structures that are of greater antiquity. From the first century, B. C., to the beginning of the seventh, A. D., there is a great number of definitely dated monuments—buildings of all kinds, temples, palaces, public baths, theatres, fortresses, churches, private residences and tombs of greater or less architectural importance. The great periods represented are the Nabatæan of the first century B.C.–A. D., the Roman of the second and third centuries, A. D., and the Christian of the fourth to the seventh century. The most important of these are the Nabatæan and the Christian, the former as representing the earliest pre-Christian Arabic civilization. The monuments of this period show great dignity of design, grandeur of scale, richness of decoration and fineness of execution, both in the art of building and of carving. This architectural style has been, hitherto, practically unknown. The buildings of the Christian period also present a style of architecture that stands by itself. They illustrate, in well preserved examples, every variety of structure required by a highly civilized people. We have found here the

earliest churches with definitely dated inscriptions upon them—perfectly developed basilicas of the fourth century—public baths as luxurious as those of pagan times, the best preserved private houses of antiquity, not excepting those of Pompeii, and mausoleums of great magnificence.

The architecture of the Nabatæan period, in its earliest monuments, shows no influence of Greek art; its ornament is purely oriental, its profiles unique, and its decorative patterns, either geometrical or taken from the animal or vegetable worlds, are full of oriental feeling. The great temple precinct of Ba'al Shamîn, at a place called Sî', is a wonderful aggregation of structures including, besides the main temple, a colonnaded court (called a *theatron* in an inscription), two other enclosed and paved courts with monumental gateways, two minor temples, and a paved, sacred way.

The Roman period is of great interest for the reason that Syrian builders under Roman domination were far freer in their employment of classical details of construction and of ornament than were the architects of Rome. The pendentive, for instance, the detail of construction by means of which a dome is accommodated to a square substructure, was used in Central Syria in the second and third centuries; it did not appear in Europe until Byzantine times in the sixth century. Classical ornament in the hands of these Syrian architects was infused with a luxuriant grace unknown at Rome. Some of the most stupendous and some of the richest buildings of the Roman Empire were erected in Syria.

The Christian architecture shows absolute independence of Rome on the one side and of Constantinople on the other. It is a curious blending of ancient Greek with oriental motives. The constructive principles are largely Greek, the mouldings are Greek, but the carved ornament is distinctly Asiatic. The Christian period of architecture in Syria did not inaugurate a decline, as it did in Europe, but begins a new fresh and vigorous style that was cut off in its prime by the rise of Mohammedanism.

In addition to our records of these monuments, we here collected many coins, dating from the third century, B. C., to the seventh, A. D., making a series almost complete that covers a period of a thousand years. Many of these coins were minted at Antioch,

Damascus, Bosra or one of the smaller Syrian cities. Smaller collections of glass and terra cotta, and a few specimens of ornaments in gold, silver and bronze, together with beads and seals, serve to indicate the high skill of various craftsmen in Syria 1,500 years ago.

Over a thousand inscriptions in Greek and Latin were copied by the Princeton Expedition. They are chiefly useful in giving dates to the architecture, though a few of them are important historically or linguistically. The number of Semitic inscriptions is smaller, but more important, perhaps, to the science of epigraphy because they are rarer. These embrace inscriptions in Nabatæan, Palmyrene, Syriac, Safaïtic (so-called), Cufic and Arabic.

Combining the study of topography, of architecture with its auxiliary arts, like sculpture, wall painting and mosaic work, and of inscriptions, we should be able to reconstruct the ancient civilization of central Syria at different periods with considerable accuracy.

The reconstruction of an early Christian civilization that was rich and prosperous, even luxurious, is especially interesting; for nowhere else in the world, so far as it is known, are there such abundant remains of the monuments, the utensils, the ornaments, the things in daily use that go to make up the unwritten documents of that period, and the inscriptions provide many of the written sort.

The maps, the monuments of architecture, and the inscriptions are to be published together, beginning at once, in a series of fascicules. Each fascicule is to be devoted to an important site or a group of less important sites, and will contain the results of the work of each member of the expedition.

A PRELIMINARY STUDY OF SOME MODERN MICROMETERS

By MARSHALL D. EWELL.

(*Read April 19, 1907.*)

With the advent of the International Bureau of Weights and Measures and our own National Bureau of Standards, each of which has done and is doing a great work in the extension of a uniform and correct system of standards throughout the world, it was to be expected that this uniformity and precision would be exemplified in the stage micrometers manufactured and for sale by makers of scientific instruments in this and other countries. With a view to determining how far this expectation has been realized the writer has collected as many stage micrometers as he conveniently could by purchase from dealers or through the courtesy of friends, and has measured from five to ten spaces on each with great care and herewith presents in part the results of such measurements. The instruments used were an excellent stand made especially for micrometry by the late W. H. Bulloch, a very stable stand made by the Spencer Lens Co., filar micrometers by Zeiss, The Spencer Lens Co., Bausch and Lomb, Zentmayer and others, and a Bausch and Lomb opaque illuminating one-inch objective, a Zeiss A A, and a Leitz No. 3 objective. From five to ten readings were taken at each end of the space measured and the mean taken. The errors in total length of the several spaces measured have not yet been determined, though the observations have been made; and the results here given are the relative errors only or the differences between each designated space and the mean of all the measured spaces. These scales were all, except where otherwise designated, ruled on glass, and in many instances the lines have deteriorated to a considerable extent, though not so as to invalidate the measurements. A few were photographs and one or two had very coarse lines, so coarse as to render them unsuitable for any but low powers.

A + sign indicates that the measured space is too short and a — sign that the space is too long. The unit of measurement is the micron $= \frac{1}{1000}$ mm.

No. I. Glass Micrometer by Bausch and Lomb—Metric scale.

Space Measured	Relative Correction.
First $\frac{1}{10}$ mm	— 1.0 micron.
Second $\frac{1}{10}$ mm	— 1.8 micron.
Third $\frac{1}{10}$ mm	+ 1.0 micron.
Fourth $\frac{1}{10}$ mm	+ 1.0 micron.
Fifth $\frac{1}{10}$ mm	+ 0.8 micron.

No. II. Photograph by Möller.

Space.	Relative Correction.
First $\frac{1}{10}$ mm	0.0 micron.
Second $\frac{1}{10}$ mm	— 0.1 micron.
Third $\frac{1}{10}$ mm	0.0 micron.
Fourth $\frac{1}{10}$ mm	+ 0.2 micron.
Fifth $\frac{1}{10}$ mm	— 0.1 micron.

No. III. Glass Scale ruled on the Engine owned by Cornell University.

Space.	Relative Correction.
First $\frac{1}{10}$ mm	+ 0.2 micron.
Second $\frac{1}{10}$ mm	+ 0.3 micron.
Third $\frac{1}{10}$ mm	0.0 micron.
Fourth $\frac{1}{10}$ mm	0.0 micron.
Fifth $\frac{1}{10}$ mm	— 0.4 micron.

No. IV. Glass Scale by Zentmayer.

Space.	Relative Correction
First $\frac{1}{10}$ mm	— 0.4 micron.
Second $\frac{1}{10}$ mm	— 0.5 micron.
Third $\frac{1}{10}$ mm	0.0 micron.
Fourth $\frac{1}{10}$ mm	+ 0.5 micron.
Fifth $\frac{1}{10}$ mm	+ 0.4 micron.

No. V. Glass Scale by E. Leitz.

Space.	Relative Correction.
First $\frac{1}{10}$ mm	+ 0.1 micron.
Second $\frac{1}{10}$ mm	+ 0.1 micron.
Third $\frac{1}{10}$ mm	+ 0.1 micron.
Fourth $\frac{1}{10}$ mm	— 0.1 micron.
Fifth $\frac{1}{10}$ mm	— 0.2 micron.

No. VI. Glass Scale by Zeiss.

Space.		Relative Correction.
First	$\frac{1}{10}$ mm	— 0.2 micron.
Second	$\frac{1}{10}$ mm	+ 0.2 micron.
Third	$\frac{1}{10}$ mm	+ 0.7 micron.
Fourth	$\frac{1}{10}$ mm	— 0.3 micron.
Fifth	$\frac{1}{10}$ mm	— 0.4 micron.

No. VII. Glass Scale by Powell and Leeland.

Space.		Relative Correction.
First	$\frac{1}{10}$ mm	+ 0.7 micron.
Second	$\frac{1}{10}$ mm	— 1.0 micron.
Third	$\frac{1}{10}$ mm	+ 0.9 micron.
Fourth	$\frac{1}{10}$ mm	— 0.5 micron.
Fifth	$\frac{1}{10}$ mm	— 0.1 micron.

No. VIII. Glass Scale by Watson.

Space		Relative Correction.
First	$\frac{1}{10}$ mm	+ 0.5 micron.
Second	$\frac{1}{10}$ mm	— 0.5 micron.
Third	$\frac{1}{10}$ mm	+ 2.9 micron.
Fourth	$\frac{1}{10}$ mm	— 1.7 micron.
Fifth	$\frac{1}{10}$ mm	— 1.2 micron.

No. IX. English Scale on Speculum Metal by the late Professor W. A. Rogers.

Space		Relative Correction.
First	$\frac{1}{100}$ inch	+ 0.4 micron.
Second	$\frac{1}{100}$ inch	— 0.6 micron.
Third	$\frac{1}{100}$ inch	— 0.3 micron.
Fourth	$\frac{1}{100}$ inch	+ 0.7 micron.
Fifth	$\frac{1}{100}$ inch	+ 0.4 micron.
Sixth	$\frac{1}{100}$ inch	— 0.8 micron.
Seventh	$\frac{1}{100}$ inch	+ 0.2 micron.
Eighth	$\frac{1}{100}$ inch	— 0.3 micron.
Ninth	$\frac{1}{100}$ inch	+ 0.1 micron.
Tenth	$\frac{1}{100}$ inch	+ 0.1 micron.

No. X. Scale on Platinum Iridium, known as "Centimeter A" the Standard of the American Microscopical Society.

Space.		Correction (total).
First	$\frac{1}{10}$ mm	+ 0.20 micron.
Second	$\frac{1}{10}$ mm	+ 0.13 micron.
Third	$\frac{1}{10}$ mm	+ 0.84 micron.
Fourth	$\frac{1}{10}$ mm	— 0.60 micron.
Fifth	$\frac{1}{10}$ mm	— 0.44 micron.
Sixth	$\frac{1}{10}$ mm	+ 0.22 micron.
Seventh	$\frac{1}{10}$ mm	— 0.14 micron.
Eighth	$\frac{1}{10}$ mm	+ 0.21 micron.
Ninth	$\frac{1}{10}$ mm	— 0.02 micron.
Tenth	$\frac{1}{10}$ mm	+ 0.18 micron.

The last two scales (IX and X) were ruled from 20 to 25 years ago and are included in this list simply for the purpose of comparison with more recent productions.

The results above given need no comment and show that no advance in precision has been made in the last twenty-five years; indeed the results do not seem to equal those of the former period.

CHICAGO, April 15, 1907.